Fig. 3A

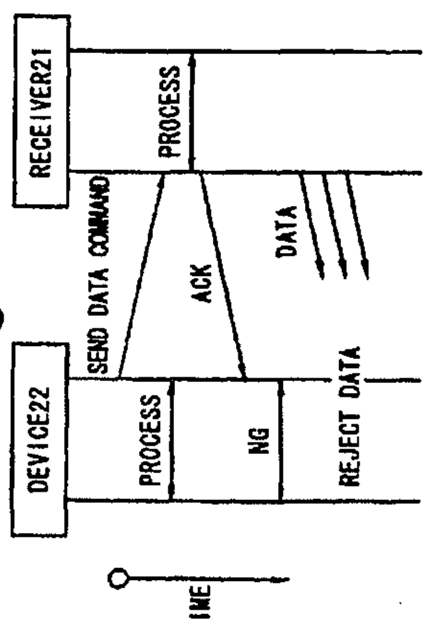

Fig. 3B

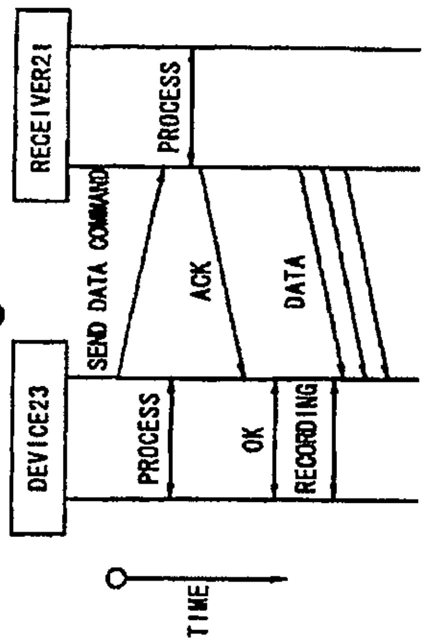

Fig. 3C

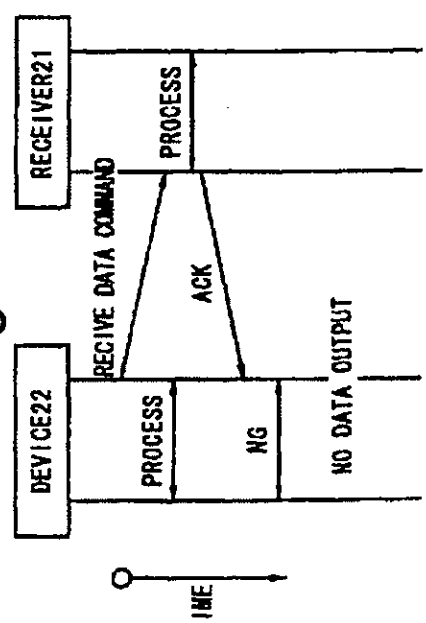

Fig. 3D

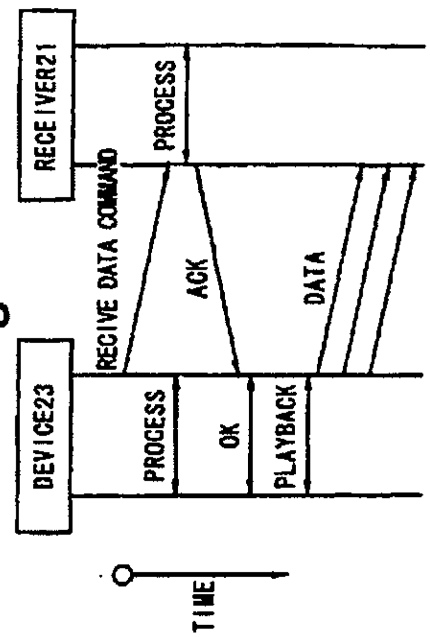

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Fig. 4

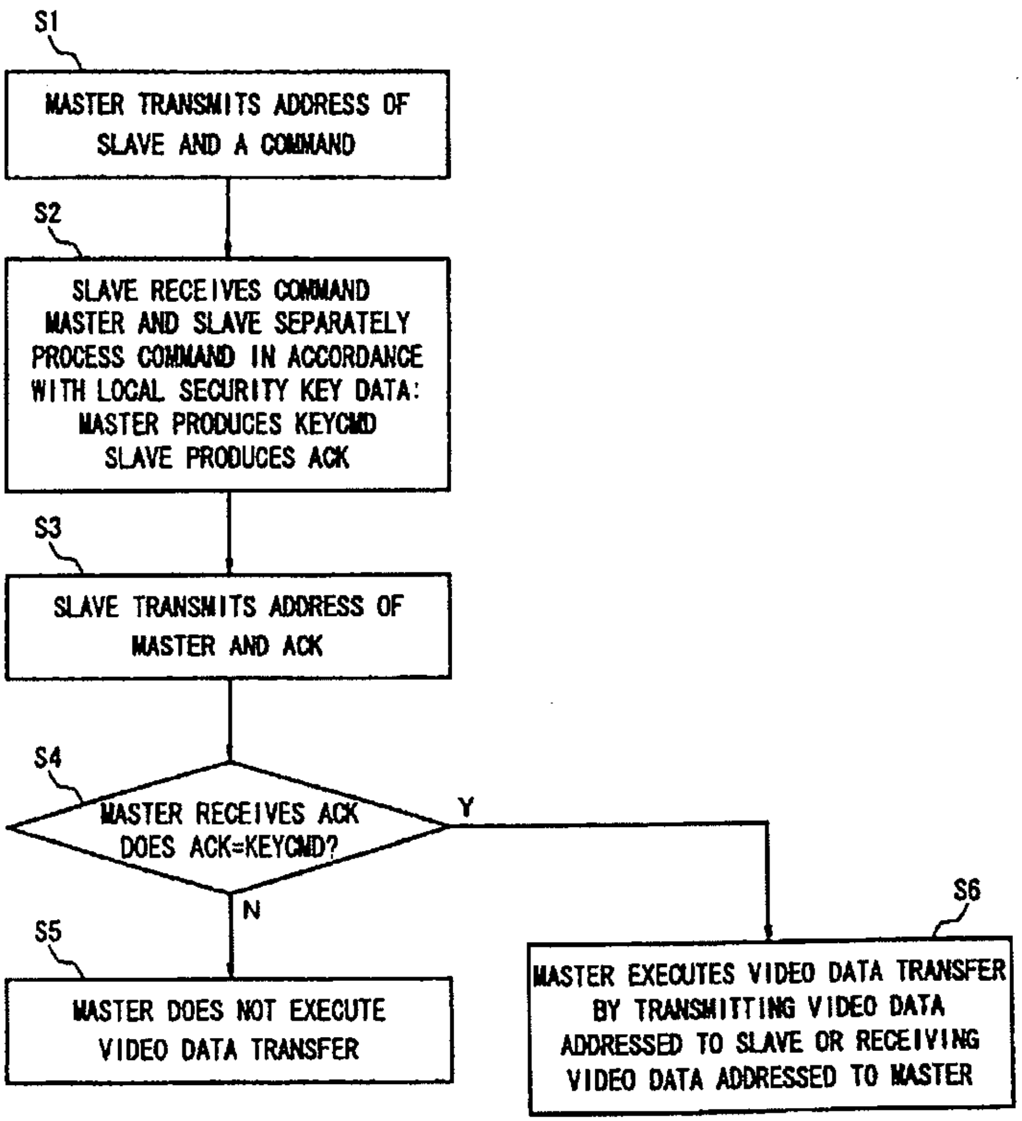

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Fig. 5

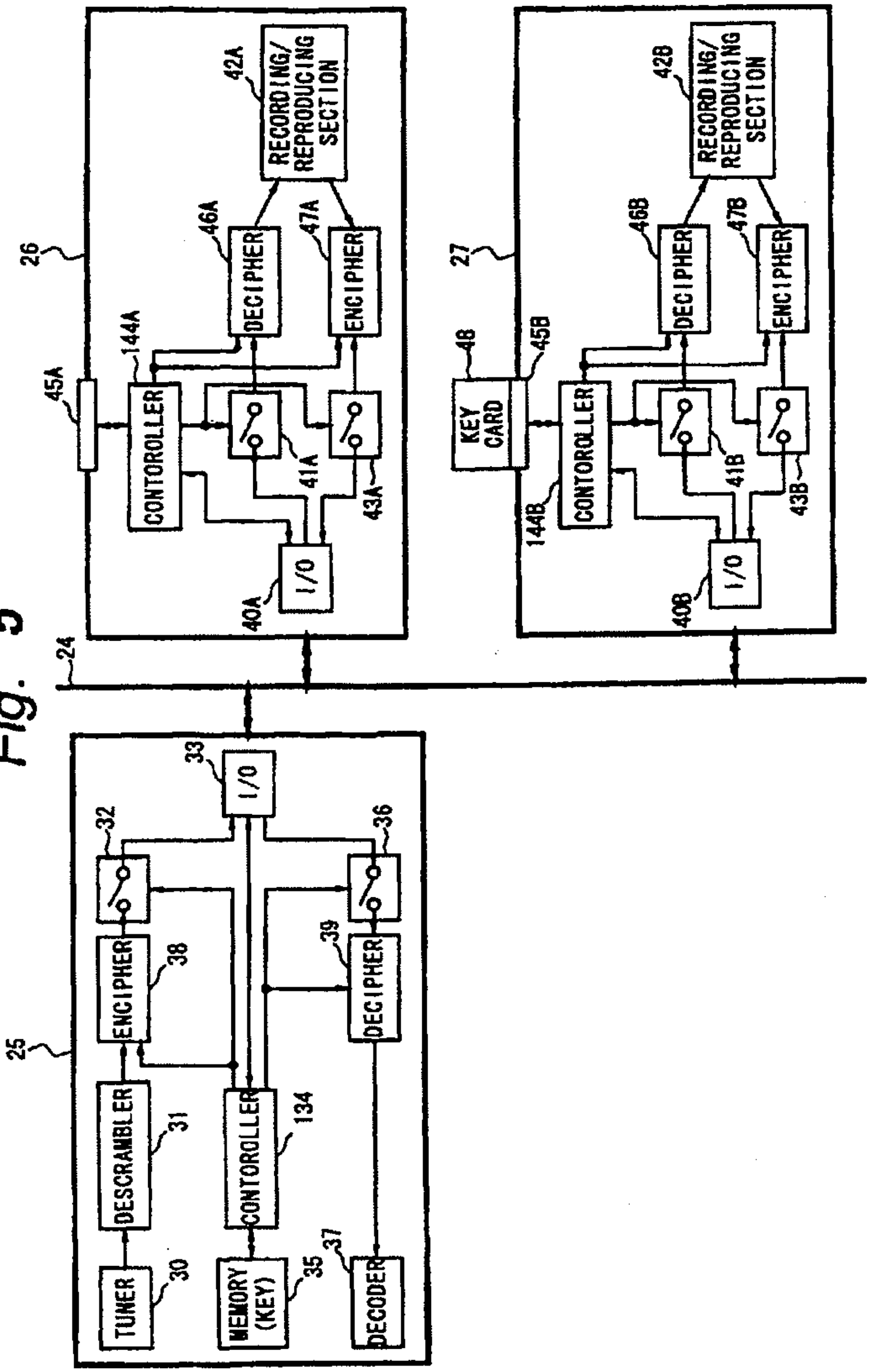

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Fig. 6B

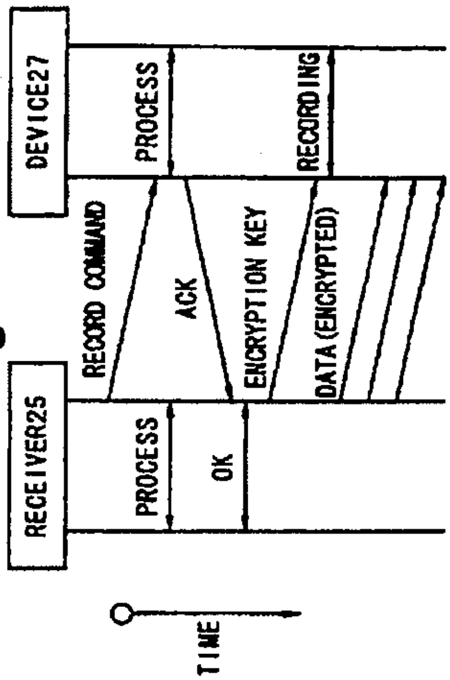

Fig. 6D

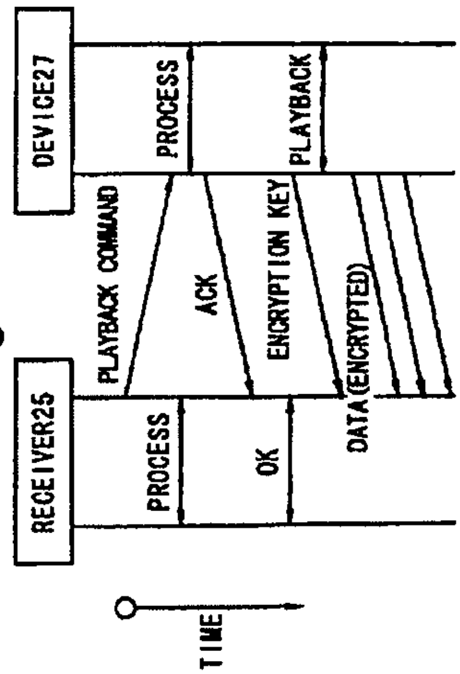

Fig. 6A

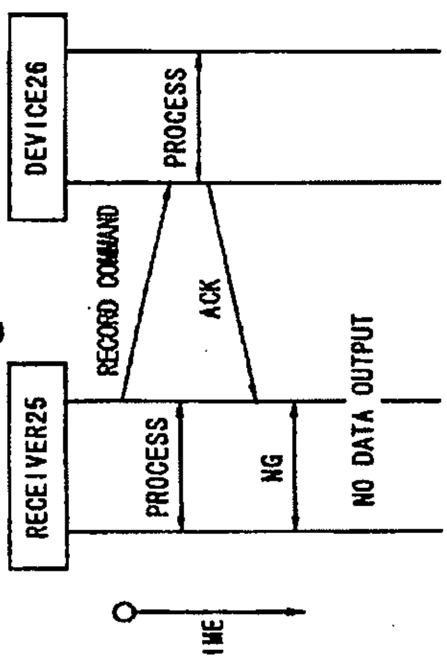

Fig. 6C

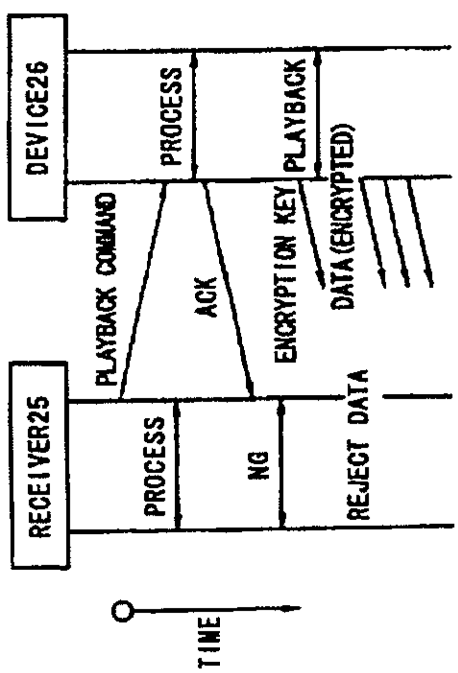

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Fig. 7B (AMENDED)

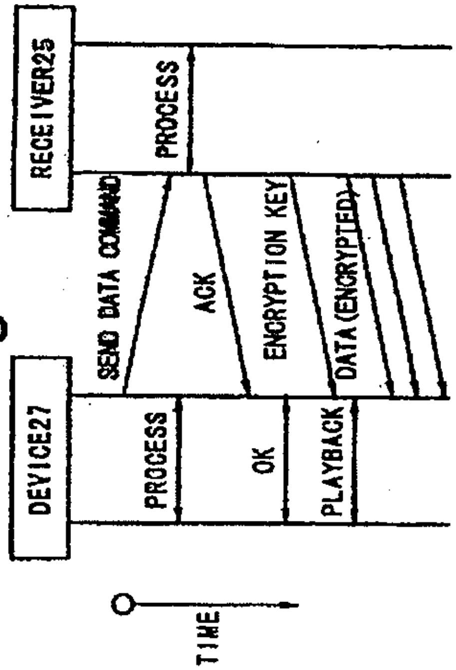

Fig. 7D

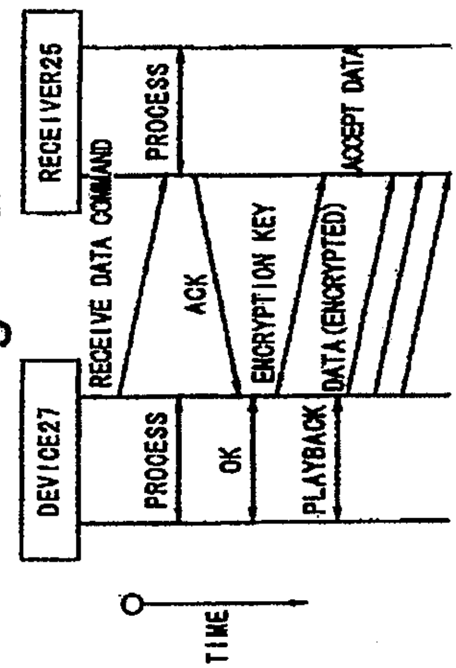

Fig. 7A

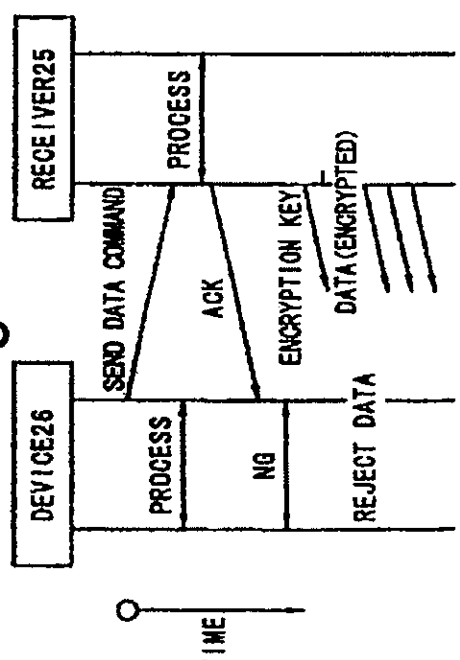

Fig. 7C (AMENDED)

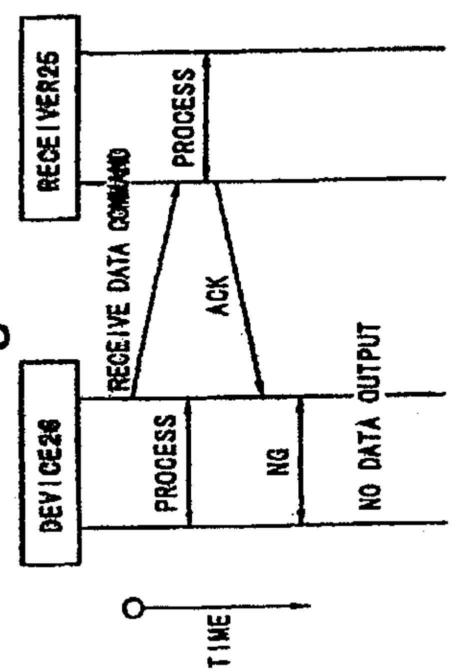

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Fig. 8

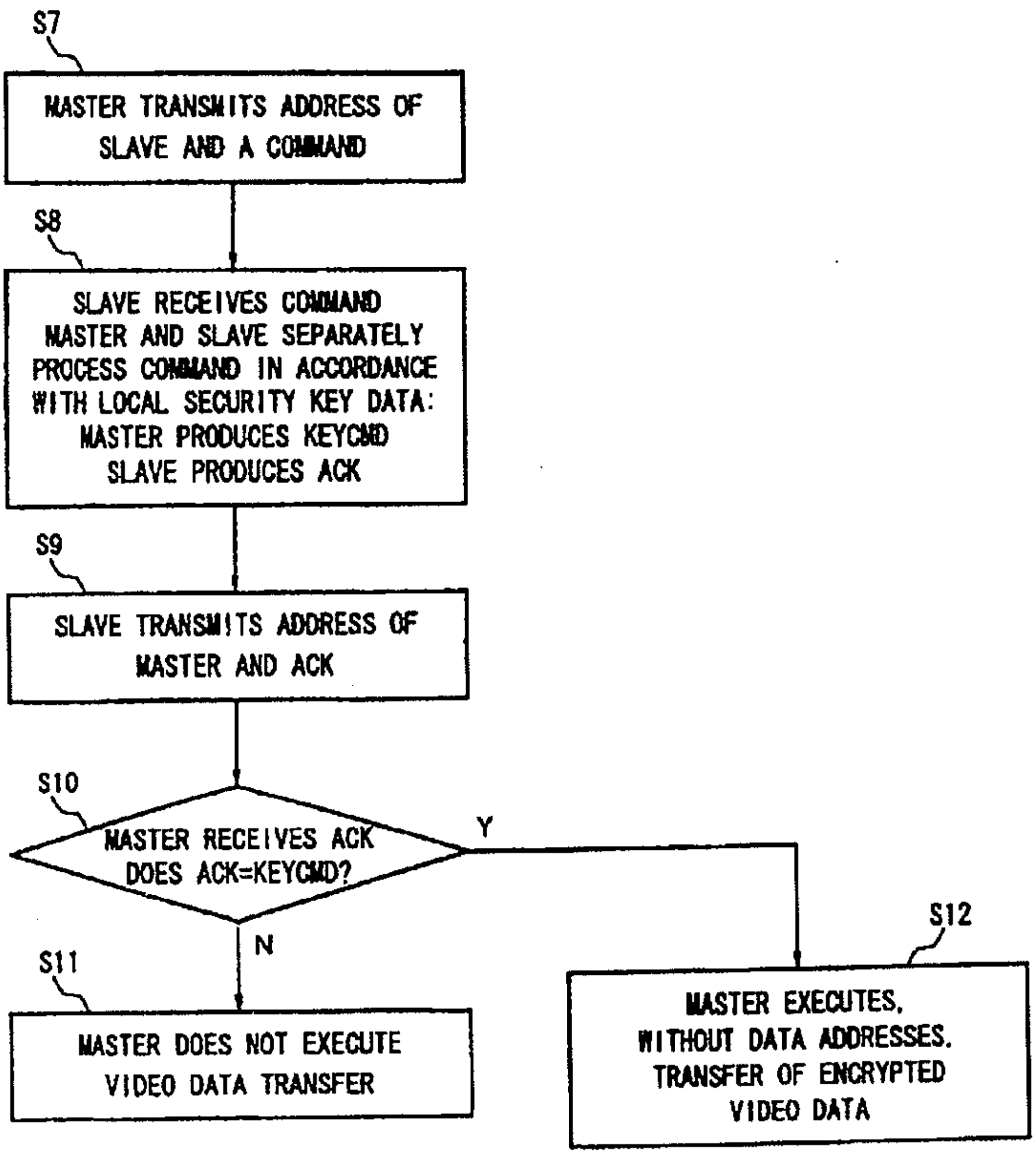

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Fig. 9

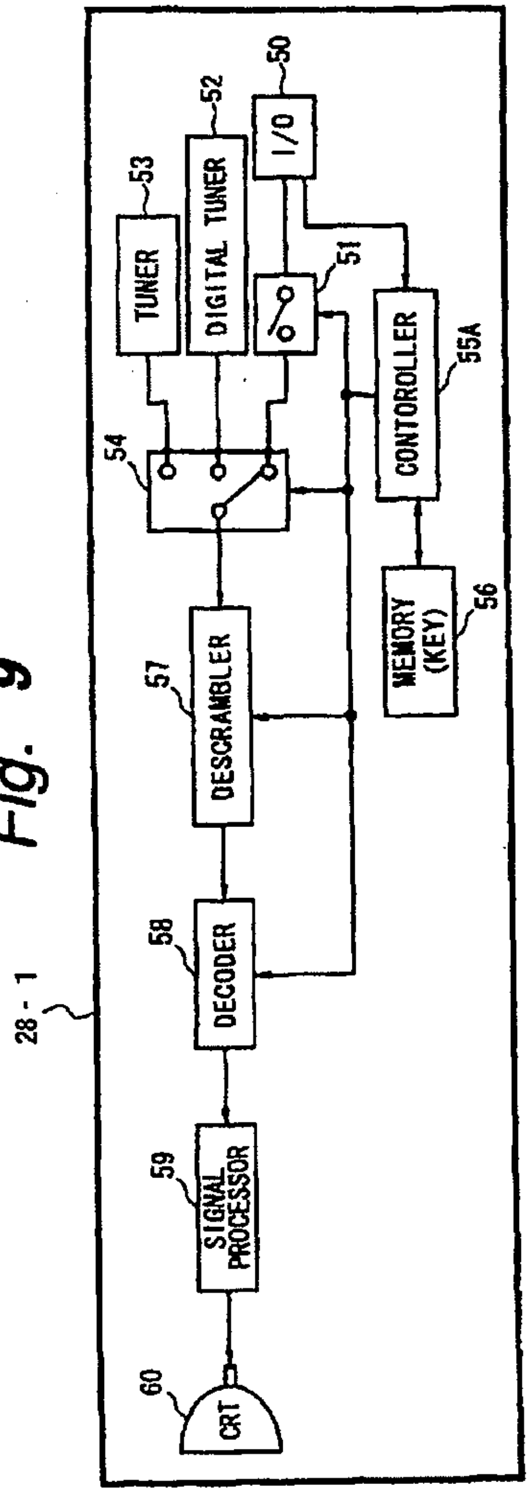

28 - 1
TUNER
53
DIGITAL TUNER
52
I/O
50
51
54
CONTOROLLER
55A
MEMORY (KEY)
56
DESCRAMBLER
57
DECODER
58
SIGNAL PROCESSOR
59
CRT
60

Fig. 10

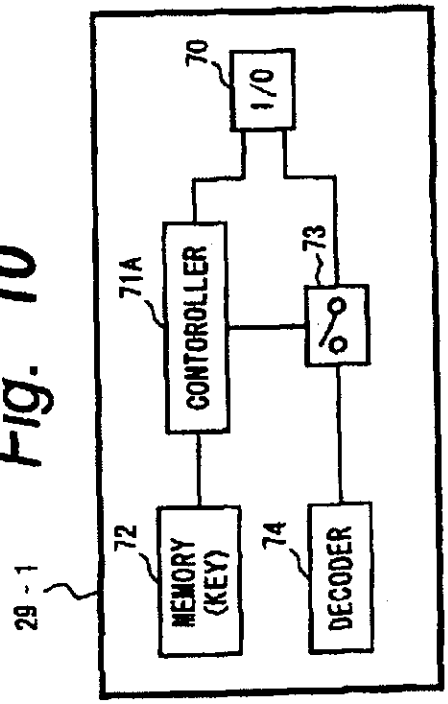

29 - 1
I/O
70
CONTOROLLER
71A
73
MEMORY (KEY)
72
DECODER
74

Fig. 11

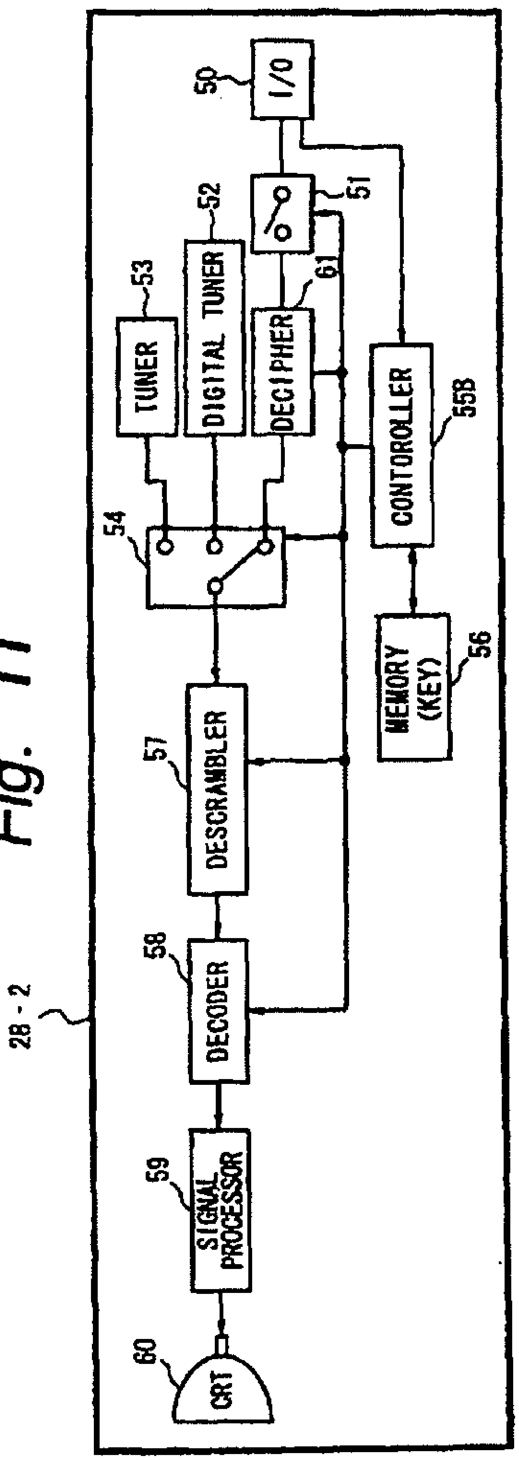
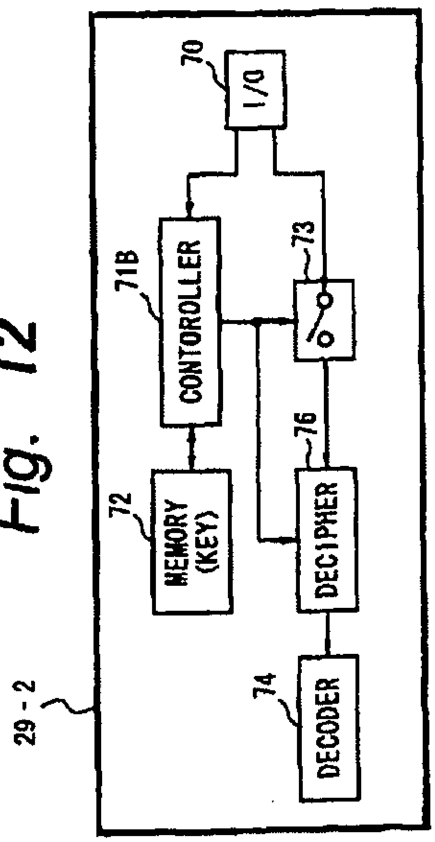


Fig. 12



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VIDEO DATA BUS COMMUNICATION SYSTEM AND METHOD

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

More than one application has been filed to reissue U.S. Pat. No. 5,699,426. This is a continuation of reissue U.S. Pat. RE38,898, which is a continuation of reissue U.S. Pat. RE38,055, which is a reissue of U.S. Pat. No. 5,699,426.

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to and is a continuation application of U.S. application Ser. No. 10/323,357, which was filed on Dec. 19, 2002, now U.S. Pat. RE38,898, and which is a continuation of U.S. application Ser. No. 09/461,136, which was filed on Dec. 14, 1999, now U.S. Pat. RE38,055, which is a reissue application of U.S. Pat. No. 5,699,426, issued Dec. 16, 1997. The entire contents of the foregoing are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a video data communication system and method in which video data is transmitted between devices connected to a data bus according to a protocol which ensures the security of the transmitted video data.

2. Description of the Related Art

Video data devices are connected to a common data bus to facilitate the communication of video data among the devices. Such devices include video signal receivers, video signal decoders, video signal recorders, video signal processing devices, video signal display devices, and video signal reproducing or playback devices. The data bus architecture has the advantage of being easy to implement, modify, and expand.

A video data bus system which conveys digital video data signals has the added advantage of substantially preserving the integrity of digital video signals transmitted on the bus. Such a system may transmit video data at great speeds without degrading the quality of the transmitted signal. Such a system is particularly useful for reproducing and disseminating copyrighted video data.

To preserve the value of copyrighted video data, a data bus communication system is needed that can selectively prevent certain devices connected to the bus from accessing certain video data but allowing such devices to access other video data. Also, a flexible communication protocol is needed to facilitate the secure and organized flow of video data through a video data bus system.

OBJECTS AND SUMMARY OF THE INVENTION

An object of the present invention is to provide a communication system in which the security of video data transmitted on a data bus is maintained.

Another object of the present invention is to prevent the unauthorized retrieval, reproduction, or display of video data transmitted on a video data bus.

Yet another object of the present invention is to provide a method for securely communicating video data among particular devices connected to a common video data bus.

A further object of the invention is to provide a communication system in which a device connected to a common video bus is able to address particular other devices for the transfer of video data thereamong.

A still further object of the invention is to provide a communication system in which devices connected to a common data bus can issue control signals to other devices to initiate specific types of video data transfers.

Another object of the present invention is to provide a communication system in which video data signals are transmitted on a video data bus without specifically included address signals.

In accordance with one aspect of the present invention, a method for communicating video data via a data bus between a master device and a slave device which are each coupled to the bus, comprises the steps of transmitting a slave address of the slave device and a command from the said master device to said data bus, generating, at said master device, a KEYCMD signal as a function of said command and a master security key, receiving, at said slave device from said data bus, said slave address and said command and recognizing said slave address as corresponding to said slave device, generating, at said slave device, an ACK signal as a function of said command and a slave security key, transmitting from said slave device to said data bus a master address of said master device and said ACK signal, receiving, at said master device from said data bus, said master address and said ACK signal and recognizing said master address as corresponding to said master device, comparing said KEYCMD signal generated by said master device which said ACK signal received by said master device, and executing a data transfer between said master device and said slave device if said KEYCMD signal corresponds to said ACK signal.

In accordance with another aspect of the present invention, in a system for communicating video data between at least one master device having a master address and at least one slave device having a slave address by way of a data bus coupled to said master device and to said slave device; said master device includes means for transmitting to said data bus said slave address and a command, means for generating a KEYCMD signal as a function of said command and a master security key, means for receiving from said data bus said master address and an ACK signal, means for recognizing said master address as corresponding to said master device, means for comparing said KEYCMD signal, and means for receiving said video data from said data bus if said KEYCMD signal corresponds to said ACK signal; and said slave device includes means for receiving from said data bus said slave address and said command, means for recognizing said slave address as corresponding to said slave device, means for generating said ACK signal as a function of said command and a slave security key, and means for transmitting to said data bus said master address, said ACK signal, and said video data.

In accordance with still another aspect of this invention, in a system for communicating video data between at least one master device having a master address and at least one slave device having a slave address by way of a data bus coupled to said master device and to said slave device; and said master device includes means for transmitting to said data bus said slave address and a command, means for generating a KEYCMD signal as a function of said command and a master security key, means for receiving from said data bus said master address and an ACK signal, means for recognizing said master address as corresponding to said master device, means for comparing said KEYCMD signal and said ACK

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signal, and means for transmitting to said data bus said video data if said KEYCMD signal corresponds to said ACK signal; and said slave device includes means for receiving from said data bus said slave address, said command and said video data, means for recognizing said slave address as corresponding to said slave device, means for generating said ACK signal as a function of said command and a slave security key, and means for transmitting to said data bus said master address and said ACK signal.

In accordance with a feature of this invention, in executing a data transfer, the data in said master device is encrypted according to an encryption key and the data in said slave device is decrypted according to said encryption key, and said slave address and said encryption key are transmitted from said master device to said data bus and said encryption key and said slave address are received at said slave device from said data bus with said slave address being recognized as corresponding to said slave device. Alternatively, is executing a data transfer, the data in said slave device is encrypted according to an encryption key and said data in said master device is decrypted according to said encryption key, said master address and said encryption key are transmitted from said slave device to said data bus and said master address and said encryption key are received from said data bus at said master device with said master address being recognized as corresponding to said master device.

The above, and other objects, features and advantages of the present invention will become apparent from the following detailed description of illustrative embodiments when read in conjunction with the accompanying drawings in which the same components are identified by the same reference numerals.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of a video data communication system according to a first embodiment of the present invention;

FIGS. 2(a)-(d) are process timing diagrams to which reference will be made in explaining the operation of the video data communication system of FIG. 1;

FIGS. 3(a)-(d) are additional process timing diagrams to which reference will be made in explaining the operation of the video data communication system of FIG. 1;

FIG. 4 is a flow diagram to which reference will be made in explaining the general sequence of communication and processing conducted by the video data communication system of FIG. 1;

FIG. 5 is a schematic diagram of a video data communication system according to a second embodiment of the present invention;

FIGS. 6(a)-(d) are process timing diagrams to which reference will be made in explaining the operation of the video data communication system of FIG. 5;

FIGS. 7(a)-(d) are additional process timing diagrams to which reference will be made in explaining the operation of the video data communication system of FIG. 5;

FIG. 8 is a flow diagram to which reference will be made in explaining the general sequence of communication and processing conducted by the video data communication system of FIG. 5;

FIG. 9 is a schematic diagram of a display device compatible with the video data communication system of FIG. 1;

FIG. 10 is a schematic diagram of a decoding device compatible with the video data communication system of FIG. 1;

FIG. 11 is a schematic diagram of a display device compatible with the video data communication system of FIG. 5; and

FIG. 12 is a schematic diagram of a decoding device compatible with the video data communication system of FIG. 5.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A first embodiment of the video data communication system according to the present invention is illustrated in FIG. 1. As explained in the following, it is preferred that the video data communication system be specifically adapted to receive, process, and transmit digital video data. Nevertheless, it should be appreciated that this system can be modified to accommodate other digital data or analog signals without departing from the scope of the invention. As it is understood that the system can easily be implemented to accommodate other types of data, the following is specifically directed towards a digital video data communication system to simplify explanation of the invention.

The video data communication system is generally comprised of a receiver **21**, a data bus **24**, and one or more peripheral devices. The peripheral devices, depending on their particular configurations, may transmit and/or receive control signals and/or video data through data bus **24**. Two such peripheral devices are illustrated in FIG. **1**, specifically, a recording/reproducing device **22** and a recording/reproducing device **23**. Each of receiver **21**, device **22**, and device **23** are connected to data bus **24** and are capable of transmitting and receiving control signals and video data through data bus **24**.

Receiver **21** is suited for receiving, descrambling, and decoding an input digital video signal. Specifically, receiver **21** is comprised of a tuner **30**, a descrambler **31**, a switch **32**, an input/output port **33**, a controller **34**, a memory **35**, a switch **36**, and a decoder **37**. Preferably, the input digital video signal is a satellite broadcast digital video signal acquired by a satellite antenna system. Alternatively, the input digital video signal is acquired from any of a number of other transmission media, such as a land-based broadcast system, a cable television system, or a fiber optic network.

Tuner **30** receives an input digital video signal (not shown) and selects a particular digital video signal or channel therefrom. Preferably, tuner **30** can be controlled by a user to select among a number of different video signals. Tuner **30** is coupled to descrambler **31**, and provides a selected digital video signal thereto.

Descrambler **31** descrambles a scrambled digital video signal. As is well known in the art, transmitted video signals are commonly scrambled or coded by a signal provider to prevent unauthorized reception of the video signal. Descrambler **31** descrambles, as needed, the selected digital video signal provided by tuner **30** and provides an unscrambled version of the digital video signal to switch **32**. In an alternate embodiment, a direct connection (not shown) between descrambler **31** and decoder **37** is provided to carry the unscrambled signal directly to decoder **37**.

Switch **32** is coupled to descrambler **31**, controller **34**, and input/output (I/O) port **33**. In accordance with a switch signal provided by controller **34**, switch **32** closes to connect descrambler **31** with I/O port **33**. Switch **36** is connected to decoder **37**, controller **34**, and I/O port **33**. In accordance with another switch signal provided by controller **34**, switch **36** closes to connect decoder **37** with I/O port **33**. I/O port **33** is further coupled to data bus **24** and controller **34**.

Through closed switch **36**, decoder **37** receives a coded digital video signal from I/O port **33**. As is well known in the art, video signals are commonly compressed or otherwise coded to facilitate their transmission through a transmission

medium. Decoder 37 decodes, as needed, a coded digital video signal to produce an uncoded digital video signal. Decoder 37 provides the uncoded digital video signal to a video display device (not shown) for display to a user. It is preferred that decoder 37 is adapted to decode digital video signals encoded in accordance with the Moving Picture Image Coding Experts Group (MPEG) standard.

Memory 35 is a storage device for storing one or more security keys. Memory 35 is coupled to controller 34 and stores or provides security keys and other data as required by controller 34. In response to commands provided by a user, or according to a pre-stored set of instructions, controller 34 transmits or receives address, control and data signals, through I/O port 33, to or from data bus 24. By manipulating switch signals provided to switches 32 and 36, controller 34 controls the flow of digital video data through I/O port 33. In an alternate embodiment, controller 34 further controls the operation of I/O port 33 directly with I/O port control signals and monitors data flowing through I/O port 33.

Recording/reproducing device 22 is comprised of an I/O port 40A, a switch 41A, a recording/reproducing section 42A, a switch 43A, a controller 44A, and a card port 45A. I/O port 40A is coupled to data bus 24, controller 44A, switch 41A, and switch 43A. I/O port 40A routes address, control, and data signals to and from data bus 24 and controller 44A. I/O port 40A routes data signals to switch 41A and routes data signals from switch 43A. In an alternate embodiment, address and control signals are also routed through I/O port 40A to or from switches 41A and 43A. Switch 41A is further coupled to controller 44A and section 42A. Similarly, switch 43A is further coupled to controller 44A and section 42A.

According to switch commands from controller 44A, switch 41A closes to connect I/O port 40A and section 42A. Also, according to switch commands from controller 44A, switch 43A closes to connect section 42A and I/O port 40A. Alternatively, switches 41A and 43A may be replaced with a single bi-directional switch (not shown) controlled by controller 44A and connecting I/O port 40A and section 42A.

Recording/reproducing section 42A records data supplied through switch 41A. Section 42A reproduces prerecorded data and supplies the reproduced data to switch 43A. Preferably, section 42A is a digital video tape recording/reproducing device (VTR).

Card port 45A is adapted to mechanically, electronically, or otherwise engage a key card 48 and to obtain security key data or other information therefrom. Key card 48, which is shown engaged in device 23 in FIG. 1, comprises an active or passive device, as is well known in the art. Card port 45A is coupled to controller 44A and facilitates the communication of signals between controller 44A and an engaged key card. While a key card is not installed in card port 45A, card port 45A responds to signals from controller 44A by returning a signal that is not a valid security key.

In response to commands provided by a user, or according to a pre-stored set of instructions controller 44A transmits to or receives from data bus 24, through I/O port 40A, address, control and data signals. By manipulating switch signals provided to switches 41A and 43A, controller 44A controls the flow of digital video data through I/O port 40A. In an alternate embodiment, controller 44A may control the operation of I/O port 40A directly with I/O port control signals and monitor data flowing through I/O port 40A.

As illustrated, device 23 is substantially the same as device 22, like elements being denoted by like reference numerals with the exception of the terminating letter A and B. Key card 48, shown attached to card port 45B of device 23, stores a valid security key corresponding to a security key stored in memory 35.

Operation of the first embodiment of the video data communication system will be described below. One of the most important features of this first embodiment is that each signal transmitted via data bus 24 is accompanied by an address signal corresponding to an address of a particular device, each device attached to data bus 24 having at least one address. Communication of signals between selected devices includes communication of an address of the device intended as the recipient of the transmitted signal. Each device connected to data bus 24 reads or writes, as appropriate, signals on data bus 24 when the device detects its own address on the bus. Signals accompanying addresses for other devices are ignored. In this manner, data are securely transferred between a transmitting device and a selected destination device.

This communication protocol allows for many different sequences of signal transfer between devices connected to data bus 24. Examples of these signal transfer sequences, implemented in different modes of operation of the present invention, will be described in detail below. In one mode of operation, broadcast digital video data signals are received by receiver 21 and transmitted to data bus 24 for display by a display device (not shown), for recording by a recording device, or for other signal processing. In another mode, prerecorded video data are reproduced by a peripheral device and transmitted to a decoding device for decoding and subsequent display. In still another mode, prerecorded video data are reproduced by one peripheral device and transmitted to another peripheral device which records the video data.

In a first broadcast display mode, receiver 21 receives a broadcast signal and suitably processes it for display by a video display (not shown). Tuner 30 selectively receives a broadcast signal and supplies the signal to descrambler 31. Descrambler 31 descrambles the broadcast signal and provides a descrambler version of the signal to switch 32. Controller 34 outputs switch signals that cause switches 32 and 36 to close and outputs I/O port control signals to cause I/O port 33 to couple switches 32 and 36 together. The descrambled video signal propagates through switch 32, I/O port 33, and switch 36, to decoder 37. Decoder 37 decodes the descrambled video signal and supplies the decoded signal to a video display (not shown). When a direct connection between descrambler 31 and decoder 37 is provided, the descrambled signal is supplied directly to decoder 37, bypassing switch 32, switch 36, and I/O port 33.

In a second broadcast display mode, receiver 21 receives a broadcast video signal and supplies the broadcast signal to a display device (not shown) connected to data bus 24. An example of such a display device is illustrated in FIG. 9 and will be described in detail in a later section. As in the first broadcast display mode, tuner 30 selectively receives a broadcast signal and provides the signal to descrambler 31. Descrambler 31 descrambles the broadcast video signal to produce a descrambled video signal. Controller 34 issues an address signal corresponding to a selected display device and a display command, and appropriately manipulates I/O port 33 to route the address signal and display command to data bus 24.

The display device (not shown in FIG. 1) reads the address on data bus 24, recognizes the address as its own, and reads the accompanying display command from data bus 24. The display device processes the display command to

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generate an ACK signal and transmits an address of receiver 21 along with the ACK signal to data bus 24. The address and ACK signal supplied by the display device are received by controller 34 via I/O port 33.

Controller 34 retrieves a security key from memory 35 and generates a KEYCMD signal as a function of the display command and the retrieved security key. The KEYCMD signal is then compared to the received ACK signal. If the ACK address is equal to the KEYCMD signal, then controller 34 transmits an address corresponding to the display device to data bus 24. Controller 34 also issues a switch command to switch 32, causing it to close, and an I/O port control signal to I/O port 33, causing it to couple switch 32 with data bus 24. Descrambled video signal transmitted from descrambler 31 propagates through switch 32 and I/O port 33 to data bus 24.

The address signal on data bus 24 is recognized by the display device and the subsequently transmitted video data are received, processed, and displayed. Other peripheral devices connected to data bus 24 do not read the video data present on the bus if the address signal does not correspond to one of their own respective addresses.

In a recording mode of operation, receiver 21 receives a broadcast signal and transmits the broadcast signal via data bus 24 to a particular peripheral device which records the signal. Controller 34 configures I/O port 33 to couple controller 34 with data bus 24 and then transmits an address of a particular recording device along with a record command to data bus 24. Assuming, for example, that the address transmitted corresponds to an address of device 22, controller 44A, through I/O port 40A, reads the address on data bus 24, recognizes the address as its own, and reads the accompanying record command from data bus 24. Controller 44A processes the record command to generate an acknowledge (ACK) signal.

Specifically, controller 44A polls card port 45A for a security key and generates an ACK signal as a function of the received record command and the signal returned by card port 45A. Controller 44A then transmits an address of receiver 21 and the ACK signal via I/O port 40A to data bus 24. The address and ACK signal supplied by device 22 are received by controller 34 via I/O port 33.

Controller 34 retrieves a security key from memory 35 and generates a KEYCMD signal as a function of the record command and the retrieved security key. The KEYCMD signal is then compared to the received ACK signal. If the ACK signal is equal to the KEYCMD signal, then controller 34 transmits an address signal of the particular recording device to data bus 24 through I/O port 33 and configures switch 32 and I/O port 33 for the transmission of descrambled video data from descrambler 31 to data bus 24 to initiate the transfer of video data. If the ACK signal is not equal to the KEYCMD signal, then controller 34 issues a switch command signal, causing switch 32 to open, to prevent the flow of descrambled broadcast video data to data bus 24.

Since, as illustrated in FIG. 1, card port 45A of device 22 is not coupled to a card key containing a correct security key, controller 44A will generate an ACK signal which is not equal to the KEYCMD signal produced by controller 34 and no video data transfer will occur. Thus, the supply of descrambled broadcast video data to a particular recording device depends upon the installation of an appropriate key card in the card port of the particular device.

When device 23 is selected to record broadcast video data, controller 34 outputs an address of device 23 to data bus 24 through I/O port 33 along with a record command. Controller 44B, through I/O port 40B, reads the address on data bus 24, recognizes the address signal as its own and reads the accompanying record command. Controller 44B retrieves a security key from key card 48 via card port 45B. Controller 44B generates an ACK signal as a function of the received record command and the retrieved security key. Controller 44B transmits an address of receiver 21 and the ACK signal to data bus 24 through I/O port 40B.

As above, controller 34 reads the address signal and the ACK signal, generates a KEYCMD signal, and compares the ACK and KEYCMD signals. If the security key contained in key card 48 corresponds to the security key contained in memory 35, the ACK signal and the KEYCMD signal are equal. Meanwhile, controller 44B supplies a switch control signal to switch 41B, causing it to close, thereby connecting I/O port 40B with recording/reproducing section 42B. Further, I/O port 40B is configured to route video data from data bus 24 to section 42B. After verifying that the two security keys correspond, controller 34 facilitates the transmission of an address of device 23 and descrambled broadcast video data to device 23.

Controller 44B, through I/O port 40B, reads the address on data bus 24 and recognizes the address signal as its own. The accompanying descrambled video data on data bus 24 is retrieved and passed through I/O port 40B and switch 41B to section 42B for recording. As a result, recording devices having the selected address and provided with a key card 48 having the correct security key retrieve and record video data supplied by receiver 21.

In a playback mode of operation, receiver 21 initiates the playback of prerecorded video data from a peripheral device. Controller 34 transmits an address signal, corresponding to an address of a particular peripheral device, along with a playback command to data bus 24 through I/O port 33. Assuming, for example, that the address signal corresponds to an address of device 22, controller 44A, through I/O port 40A, reads the address on data bus 24, recognizes the address as its own, and reads the accompanying playback command from data bus 24. As described previously, controller 44A generates an ACK signal as a function of the playback command and a signal provided by card port 45A. Controller 44A then transmits an address of receiver 21 and this ACK signal via I/O port 40A to data bus 24. Controller 44A also issues a switch control signal to switch 43A, causing it to close, and configures I/O port 40A to connect data bus 24 and switch 43A.

Controller 34, through I/O port 33, reads the address on data bus 24, recognizes the address as its own, and reads the accompanying ACK signal. Controller 34 retrieves a security key from memory 35 and generates a KEYCMD signal as a function of the playback command and the retrieved security key. The received ACK signal is compared to the KEYCMD signal and, if they are equal, controller 34 issues a switch control signal to switch 36, causing it to close, and issues an I/O port control signal to I/O port 33, causing it to route signals from data bus 24 to switch 36. However, if the ACK signal does not equal the KEYCMD signal, then controller 34 issues a switch control signal which causes switch 36 to open.

Since device 22, as shown in FIG. 1, is not engaged with a key card having a correct security key, the ACK signal it produces will not be equivalent to the KEYCMD signal produced by controller 34. Even though recording/reproducing section 42A may output prerecorded video data to data bus 24 via switch 43A and I/O port 40A, the data will not reach decoder 37, since switch 36 will have been opened.

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In the case where controller 34 initially issues an address corresponding to device 23, controller 44B reads and recognizes the address, reads the accompanying playback command, and polls card port 45B. Key card 48, having a security key corresponding to that stored in memory 35, supplies the security key to controller 44B through card port 45B. Controller 44B generates an ACK signal as a function of the received playback command and the security key received from key card 48. The ACK signal and the address of receiver 21 are transmitted via data bus 24 to controller 34 and switch 43B is closed. Controller 34 reads and recognizes the address, reads the accompanying ACK signal, and generates a KEYCMD signal as a function of the playback command and a security key obtained from memory 35. In this instance, the ACK signal and the KEYCMD signal are equal, and accordingly, controller 34 causes switch 36 to close.

Controller 44B outputs an address of receiver 21 and recording/reproducing section 42B outputs a prerecorded video data signal to data bus 24. Controller 34 reads and recognizes the address. The accompanying video data signal is retrieved from data bus 24 and supplied through I/O port 33 and switch 36 to decoder 37. Decoder 37 decodes the prerecorded video data signal and supplies the decoded signal to a video display device (not shown). Receiver 21 thus decodes data reproduced by a peripheral device in which a key card having a correct security key is installed.

The signal processing and exchange of messages in receiver-initiated data transfers is summarized in FIGS. 2(a)-(d). In each of FIGS. 2(a)-(d), the time axis runs positive in the direction indicated by the arrow. Although not explicitly mentioned in the following discussion, it should be understood that each communication between devices includes an address of the device to which the communication is being sent.

FIG. 2(a) illustrates the interaction between receiver 21 and device 22 of FIG. 1 when receiver 21 initiates video data recording. In FIG. 2(a) receiver 21 first issues a record command to device 22. Receiver 21 then processes the record command in conjunction with a security key retrieved from memory 35 to produce a KEYCMD signal. Device 22 receives the record command and similarly processes it in conjunction with a security key retrieved from card port 45A to produce an ACK signal. Device 22 then transmits the ACK signal to receiver 21. Receiver 21 compares the received ACK signal with the KEYCMD signal to determine if they are equal. Since a key card having a correct security key is not installed in device 22, the KEYCMD signal and the ACK signal are not equal. As a result, receiver 21 determines that the ACK signal is "no good" (NG) and no data is output by receiver 21.

In FIG. 2(b), receiver 21 transmits a record command to device 23. As in the manner previously described, both receiver 21 and device 23 process the recording command to produce, respectively, a KEYCMD signal and an ACK signal. Device 23 transmits the ACK signal to receiver 21. Receiver 21 compares the KEYCMD signal and the received ACK signal. Since device 23 is engaged with a key card having a correct security key, the ACK signal and the KEYCMD are equal. Receiver 21 determines that the ACK signal is thus "OK" and initiates the transmission of video data to device 23. Device 23 records the video data it receives.

FIGS. 2(c) and 2(d) illustrate the sequence of steps which occur when receiver 21 issues a playback command to a peripheral device. In FIG. 2(c), receiver 21 transmits a playback command to device 22. Receiver 21 processes the playback command in conjunction with a security key retrieved from memory 35 to produce a KEYCMD signal. Device 22 processes the received playback command in conjunction with a security key retrieved from card port 45A to produce an ACK signal. Device 22 transmits the ACK signal to receiver 21. Receiver 21 compares the KEYCMD signal with the received ACK signal to determine if they are equal. Since a key card containing a correct security key is not installed in device 22, the ACK signal is not equal to the KEYCMD signal. Accordingly, receiver 21 determines that the ACK signal is "no good" (NG). Nonetheless, device 22 reproduces a prerecorded video signal and transmits the reproduced video data to receiver 21. Receiver 21 rejects the video data.

In FIG. 2(d), receiver 21 transmits a playback command to device 23. Receiver 21 process the playback command, as before, to produce a KEYCMD signal. Device 23 processes the received playback command in conjunction with a security key retrieved from card port 45B to produce an ACK signal. Device 23 transmits this ACK signal to receiver 21. Receiver 21 compares the KEYCMD signal to the received ACK signal to determine if they are equal. Since key card 48 is engaged in device 23 and key card 48 contains a valid security key, the ACK signal and the KEYCMD signal are equal. Accordingly, receiver 21 determines that the ACK signal is "OK". Device 23 reproduces a prerecorded video signal and transmits the reproduced video data to receiver 21. Receiver 21 accepts the video data from device 23 and decodes it, as described with reference to FIG. 1.

The signal processing and exchange of messages in peripheral device-initiated data transfers is summarized in FIGS. 3(a)-(d). In each of FIGS. 3(a)-(d), the time axis runs positive in the direction indicated by the arrow. Each communication between the devices includes an address of the device to which the communication is being sent.

FIGS. 3(a) and 3(c) illustrate the interaction between device 22 and receiver 21 of FIG. 1 when device 22 initiates the transfer of video data. In FIG. 3(a), device 22 first issues a send data command to receiver 21. Device 22 then processes the send data command in conjunction with a security key retrieved from card port 45A to produced a KEYCMD signal. Receiver 21 receives the send data command and similarly processes it in conjunction with a security key retrieved from memory 35 to produce an ACK signal. Receiver 21 then transmits the ACK signal to device 22. Device 22 compares the received ACK signal with the KEYCMD signal to determine if they are equal. Since a key card having a correct security key is not installed in device 22, the KEYCMD signal and the ACK signal are not equal. As a result, device 22 determines that the ACK signal is "no good" (NG). Nonetheless, receiver 21 attempts to transmit broadcast video data to device 22. Device 22 rejects the video data.

In FIG. 3(c), device 22 first transmits a receive data command to receiver 21. Device 22 then processes the receive data command in conjunctions with a security key retrieved from card port 45A to produce a KEYCMD signal. Receiver 21 receives the receive data command and similarly processes it in conjunction with a security key retrieved from memory 35 to produce an ACK signal. Receiver 21 then transmits the ACK signal to device 22. Device 22 compares the received ACK signal with the KEYCMD signal to determine if they are equal. Since a key card having a correct security key is not installed in device 22, the KEYCMD signal and the ACK signal are not equal. As a result, device 22 determines that the ACK signal is "no good" (NG) and no data is output by device 22.

FIGS. 3(b) and 3(d) each illustrate the sequence of operations that occur when device 23 issues a command to

receiver 21. In FIG. 3(b), device 23 first transmits a send data command to receiver 21. Device 23 processes the send data command in conjunction with a security key retrieved from card port 45B to produce a KEYCMD signal. Receiver 21 processes the send data command in conjunction with a security key retrieved from memory 35 to produce an ACK signal. Receiver 21 then transmits the ACK signal to device 23. Device 23 compares the KEYCMD signal with the received ACK signal to determine if they are equal. Since key card 48 is engaged in device 23 and key card 48 contains a valid security key, the ACK signal and the KEYCMD signal are equal. Accordingly, device 23 determines that the ACK signal is "OK". Receiver 21 transmits video data to device 23 which records the video data.

In FIG. 3(d), device 23 first transmits a receive data command to receiver 21. Device 23 processes the receive data command in conjunction with a security key retrieved from card port 45B to produce a KEYCMD signal. Receiver 21 processes the receive data command in conjunction with a security key retrieved from memory 35 to produce an ACK signal Receiver 21 then transmits the ACK signal to device 23. Device 23 compares the KEYCMD signal with the received ACK signal to determine if they are equal. Since key card 48 is engaged in device 23 and key card 48 contains a valid security key, the ACK signal and the KEYCMD signal are equal. Accordingly, device 23 determines that the ACK signal is "OK". Device 23 reproduces a prerecorded video signal and transmits the reproduced video data to receiver 21. Receiver 21 accepts the video data from device 23 and processes it, as described above.

In a dubbing mode, two peripheral devices, each installed with a key card having the same security key, reproduce and record, respectively, prerecorded video data. A master peripheral device initiates a video data transfer by transmitting to data bus 24 an address of a slave peripheral device along with a record command or a playback command. As described in the preceding, the slave device reads and recognizes the address, configures itself according to the command, and returns an address and an ACK signal. As also described in the preceding, the master device reads and recognizes the address and processes the ACK signal to determine its validity. If the ACK signal is "OK" then a data transfer according to the command is executed; otherwise, no data transfer occurs.

The communication protocol of the apparatus of FIG. 1 is summarized in the flow diagram of FIG. 4. For ease of explanation, the term "Master" is employed to indicate the device which initiates a data transfer. The term "Slave" is employed to indicate the device which is addressed by the Master.

In step S1, the Master transmits an address of the Slave and a command to data bus 24. In step S2, the Slave receives the command and the Master and the Slave, separately process the command in accordance with security key data obtained locally. The Master produces a KEYCMD signal as a function of the command and its security key. The Slave produces an ACK signal as a function of the received command and its security key.

In step S3, the Slave transmits an address of the Master and the ACK signal to data bus 24. In step S4, the Master receives the ACK signal and determines whether the ACK signal is equal to the KEYCMD signal. If the two signals are not equal, then processing follows step S5; otherwise, processing follows step S6. In step S5, the Master inhibits or simply does not execute a video data transfer between the Master and the Slave. In step S6, the Master executes a video data transfer by transmitting an address of the Slave and video data to the Slave, or by receiving and recognizing its own address and receiving video data transmitted by the Slave.

A second embodiment of the video data communication system according to the present invention is illustrated in FIG. 5. Such video data communication system is comprised of a receiver 25, a data bus 24, and one or more peripheral devices. The peripheral devices may transmit and/or receive control signals and/or video data through data bus 24. Two such peripheral devices are illustrated in FIG. 5, specifically, a recording/reproducing device 26 and a recording/reproducing device 27. Each of receiver 25, device 26, and device 27 is connected to data bus 24 and is capable of transmitting and receiving control signal and video data through data bus 24.

Receiver 25 is suited for receiving, descrambling, enciphering, deciphering, and decoding an input digital video signal. Specifically, receiver 25 is comprised of a tuner 30, a descrambler 31, a switch 32, an I/O port 33, a controller 134, a memory 35, a switch 36, an encipherer 38, a decipherer 39, and a decoder 37. Elements of FIG. 5 having the same structure and function as the corresponding elements of FIG. 1 are indicated by the same reference numeral used in FIG. 1. Tuner 30 is coupled to descrambler 31. Descrambler 31 descrambles, as needed, the selected digital video signal provided by tuner 30 and provides an unscrambled version of the digital video signal to encipherer 38.

Encipherer 38 is coupled to descrambler 31, controller 134, and switch 32. Utilizing an encryption key provided by controller 134, encipherer 38 encrypts the descrambled video signal provided by descrambler 31. The encrypted video signal is provided to switch 32.

Switch 32 is further connected to controller 134 and I/O port 33. Switch 36 is coupled to controller 134, decipherer 39 and I/O port 33. I/O port 33 is further connected to data bus 24 and to controller 134.

Decipherer 39 is coupled to controller 134 and decoder 37. Decipherer 39 receives an encryption key from controller 134 to decrypt video data provided from switch 36. Decipherer 39 supplies decrypted video data to decoder 37. Decoder 37 provides uncoded digital video signal data to a video display device (not shown).

Controller 134 is coupled to memory 35. In response to commands provided by a user, or according to a prestored set of instructions, controller 134 transmits to or receives from data bus 24, through I/O port 33, address, control and data signals. By manipulating switch signals provided to switches 32 and 36, controller 134 controls the flow of digital video data through I/O port 33. In an alternate embodiment (not shown), controller 134 directly controls the operation of I/O port 33 with I/O port control signals and monitors data flowing through I/O port 33.

Controller 134 additionally controls the encryption and decryption of video data by receiver 25. Controller 134 provides an encryption key to encipherer 38 for the encryption of descrambled video data. Similarly, controller 134 provides an encryption key to decipherer 39 to decrypt the video data supplied through switch 36. As detailed below, the encryption key is either retrieved from memory 35 or from data bus 24.

Recording/reproducing device 26 is comprised of an I/O port 40A, a switch 41A, a recording/reproducing section 42A, a switch 43A, a controller 144A, a card port 45A, a decipherer 46A, and an encipherer 47A. I/O port 40A is coupled to data bus 24, controller 144A, switch 41A, and

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switch 43A. I/O port 40A routes address, control and data signals to and from data bus 24 and controller 144A. Switch 41A is further coupled to controller 144A and decipherer 46A. Switch 43A is further coupled to controller 144A and encipherer 47A. Controller 144A is coupled to card port 45A, decipherer 46A and encipherer 47A. Recording/reproducing section 42A is coupled to decipherer 46A and encipherer 47A.

Decipherer 46A receives an encryption key from controller 144A and encrypted video data from switch 41A. Decipherer 46A decrypts the encrypted data according to the encryption key and provides decrypted data to section 42A. Encipherer 47A receives an encryption key from controller 144A and video data from section 42A. Encipherer 47A encrypts the video data according to the encryption key and provides the encrypted video data to switch 43A.

In response to commands provided by a user or according to a prestored set of instructions, and in dependence upon signals supplied by card port 45A, controller 144A transmits to or receives from data bus 24, through I/O port 40A, address, control and data signals. By manipulating switch signals provided to switches 41A and 43A, controller 144A controls the flow of digital video data through I/O port 40A. In an alternate embodiment (not shown), controller 144A further directly controls the operation of I/O port 40A with I/O port control signals and monitors data flowing through I/O port 40A.

As illustrated, device 27 is substantially the same as device 26, like elements being denoted by like reference numerals with the exception of the terminating letter A and B. Key card 48, which is shown attached to card port 45B of device 27, stores a valid security key corresponding to a security key stored in memory 35.

Operation of the second embodiment of the video data communication system will be described below. One of the most important features of this second embodiment is that each signal, except video data signals, transmitted via data bus 24 is accompanied by an address signal corresponding to an address of a particular device. As in the first embodiment, each device attached to data bus 24 is assigned a particular address. Video data is transmitted to data bus 24 in an encrypted form but without an address. Each device connected to data bus 24 and capable of receiving data therefrom has access to encrypted data on data bus 24. However, only devices having a correct encryption key can decrypt the encrypted video data. In this manner, encrypted video data is provided to devices connected to data bus 24 but only devices having a correct encryption key can decrypt and utilize the video data. The encryption key may be stored in each decrypting device or provided by the device supplying the encrypted data.

This communication protocol allows for many different sequences of signal transfer between devices connected to data bus 24. Examples of these signal transfer sequences, implemented in different modes of operation of the present invention, will be described in detail below. In one mode of operation, broadcast digital video data signals are received by receiver 25, encrypted, and transmitted to data bus 24 for receipt by a peripheral device which decrypts the signals and displays, records, or otherwise processes the decrypted data. In another mode, prerecorded video data are reproduced, encrypted, and transmitted by a peripheral device to a decoding device for decryption, decoding, and subsequent display. In still another mode, prerecorded video data are reproduced, encrypted, and transmitted by one peripheral device to another peripheral device which decrypts and records the video data.

In a broadcast encrypt/decrypt display mode, receiver 25 receives a broadcast video signal and supplies the broadcast signal to a decryption display device (not shown on FIG. 5) connected to data bus 24. An example of such a decryption display device is illustrated in FIG. 11 and will be described in detail in a later section. Tuner 30 selectively receives a broadcast signal and provides the data to descrambler 31. Descrambler 31 descrambles the broadcast video signal and provides a descrambled version of the signal to encipherer 38.

Controller 134 configures I/O port 33 to couple controller 134 with data bus 24 and then transmits an address of a particular display device along with a display command to data bus 24. The display device (not shown in FIG. 5) reads the address on data bus 24, recognizes the address as its own, and reads the accompanying display command from data bus 24. The display device processes the display command to generate an ACK signal and transmits an address of receiver 25 along with the ACK signal to data bus 24. The address and ACK signal supplied by the display device are received by controller 134 via I/O port 33.

Controller 134 retrieves a security key from memory 35 and generates a KEYCMD signal as a function of the display command and the retrieved security key. The KEYCMD signal is then compared to the received ACK signal. If the ACK signal is equal to the KEYCMD signal, then controller 134 transmits an address signal, corresponding to the selected display device, along with an encryption key, and appropriately manipulates I/O port 33 to route the address signal and the encryption key to data bus 24.

Controller 134 provides the encryption key to encipherer 38. Encipherer 38 encrypts the descrambled signal according to the encryption key and provides an encrypted signal to switch 32. Controller 134 also issues a switch command to switch 32, causing it to close, and an I/O port control signal to I/O port 33, causing it to couple switch 32 with data bus 24.

The encrypted video signal transmitted from encipherer 38 propagates through switch 32 and I/O port 33 to data bus 24. The address signal on data bus 24 is recognized by the display device and the subsequently transmitted encryption key is received and stored. Encrypted video signal is retrieved from data bus 24 and is decrypted according to the received encryption key, processed, and displayed. Other peripheral devices connected to data bus 24 read the video data present on data bus 24, however, only a device which possesses a correct encryption key can decrypt the data.

In an alternate embodiment, the receiver does not transmit an address along with the encryption key to the data bus and instead the encryption key is prestored in the display device. The encrypted data is still transmitted to data bus 24 without an address.

In an encrypt/decrypt recording mode of operation, receiver 25 receives a broadcast signal, encrypts the signal according to an encryption key, and transmits the key and the encrypted signal via data bus 24 to a particular peripheral device which records the signal. Specifically, controller 134 configures I/O port 33 to couple controller 134 with data bus 24 and then transmits an address of a particular recording device along with a record command to data bus 24. Assuming, for example, that the address transmitted corresponds to an address of device 26, controller 144A, through I/O port 40A, reads the address on data bus 24, recognizes the address as its own, and reads the accompanying record command from data bus 24. Controller 144A processes the record command to generate an ACK signal.

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Specifically, controller **144A** polls card port **45A** for a security key and generates an ACK signal as a function of the received record command and the signal returned by card port **45A**. Controller **144A** then transmits an address of receiver **25** and the ACK signal via I/O port **40A** to data bus **24**. The address and ACK signal supplied by device **26** is received by controller **134** via I/O port **33**.

Controller **134** retrieves a security key from memory **35** and generates a KEYCMD signal as a function of the record command and the retrieved security key. The KEYCMD signal is then compared to the received ACK signal. If the ACK signal is equal to the KEYCMD signal, then controller **134** transmits an address signal of the particular recording device along with the encryption key to data bus **24** through I/O port **33** and configures switch **32** and I/O port **33** for the transmission of encrypted video data from encipherer **38** to data bus **24** to initiate the transfer of video data. If the ACK signal is not equal to the KEYCMD signal, then controller **134** issues a switch command signal, causing switch **32** to open, to prevent the flow of encrypted broadcast video data to data bus **24**.

Since, as illustrated in FIG. 5, card port **45A** of device **26** is not coupled to a card key containing a correct security key, controller **144A** will, in that case, generate an ACK signal which is not equal to the KEYCMD signal produced by controller **134** and no video data transfer will occur. Thus, the supply of encrypted broadcast video data to a particular recording device depends upon the installation of an appropriate key card in the card port of the particular device.

When device **27** is selected to record broadcast video data, controller **134** outputs an address of device **27** along with a record command to data bus **24** through I/O port **33**. Controller **144B**, through I/O port **40B** reads the address on data bus **24**, recognizes the address signal as its own, and reads the accompanying record command. Controller **144B** retrieves a security key from key card **48** via card port **45B**. Controller **144B** generates an ACK signal as a function of the received record command and the retrieved security key. Controller **144B** transmits an address of receiver **25** and the ACK signal to data bus **24** through I/O port **40B**.

As above, controller **134** reads the address signal and the ACK signal, generates a KEYCMD signal, and compares the ACK and KEYCMD signals. If the security key contained in key card **48** corresponds to the security key contained in memory **35**, the ACK signal and the KEYCMD signal are equal. Meanwhile, controller **144B** supplies a switch control signal to switch **41B**, causing it to close, thereby connecting I/O port **40B** with decipherer **46B**. Further, I/O port **40B** is configured to route video data from data bus **24** to decipherer **46B**. After verifying that the two security keys correspond, controller **134** facilitates the transmission to device **27** of an address of device **27** along with an encryption key followed by encrypted video data without an address.

Controller **144B**, through I/O port **40B**, reads the address on data bus **24**, recognizes the address as its own, and reads the accompanying encryption key from data bus **24**. Controller **144B** supplies the encryption key to decipherer **46B**. Encrypted video data on data bus **24** is retrieved and passed through I/O port **40B** and switch **41B** to decipherer **46B** for deciphering according to the retrieved encryption key. Decipherer **46B** supplies decrypted video data to section **42B** for recording. As a result, recording devices having the selected address and provided with a key card **48** having a correct security key retrieve, decrypt, and record encrypted video data supplied by receiver **25**.

In a playback mode of operation, receiver **25** initiates the playback of prerecorded data from a peripheral device. Controller **134** transmits an address signal, corresponding to an address of a particular peripheral device, along with a playback command to data bus **24** through I/O port **33**. Assuming, for example, that the address signal corresponds to an address of device **26**, controller **144A**, through I/O port **40A**, reads the address on data bus **24**, recognizes the address as its own, and reads the accompanying playback command from data bus **24**. As described previously, controller **144A** generates an ACK signal as a function of the playback command and a signal provided by card port **45A**. Controller **144A** then transmits an address of receiver **25** and this ACK signal via I/O port **40A** to data bus **24**. Controller **144A** also issues a switch control signal to switch **43A**, causing it to close and configures I/O port **40A** to connect data bus **24** and switch **43A**.

Controller **134**, through I/O port **33**, reads the address on data bus **24**, recognizes the address as its own, and reads the accompanying ACK signal. Controller **134** retrieves a security key from memory **35** and generates a KEYCMD signal as a function of the playback command and the retrieved security key. The received ACK signal is compared to the KEYCMD signal and, if they are equal, controller **134** issues a switch control signal to switch **36**, causing it to close, and issues an I/O port control signal to I/O port **33**, causing it to route signals from data bus **24** to switch **36**. However, if the ACK signal does not equal the KEYCMD signal, then controller **134** issues a switch control signal which causes switch **36** to open.

Since a key card having a correct security key is not installed in device **26**, the ACK signal produced by device **26** will not be equivalent to the KEYCMD signal produced by controller **134**. Even though recording/reproducing section **42A** may output encrypted prerecorded video data to data bus **24** via switch **43A** and I/O port **40A**, the data will not reach decoder **37**, since switch **36** will have been opened.

In the case where controller **134** initially issues an address corresponding to device **27**, controller **144B** reads and recognizes the address, reads the accompanying playback command, and polls card port **45B**. Key card **48**, having a security key corresponding to that stored in memory **35**, supplies the security key to controller **144B** through card port **45B**. Controller **144B** generates an ACK signal as a function of the received playback command and the security key received from key card **48**. The ACK signal and the address of receiver **25** are transmitted via data bus **24** to controller **134** and switch **43B** is closed. Controller **134** reads and recognizes the address, reads the accompanying ACK signal, and generates a KEYCMD signal as a function of the playback command and a security key obtained from memory **35**. In this instance, the ACK signal and the KEYCMD signal are equal, and accordingly, controller **134** causes switch **36** to close.

Controller **144B** outputs an address of receiver **25** along with an encryption key to data bus **24**. Recording/reproducing section **42B** outputs a prerecorded video data signal to encipherer **47B** which encrypts the signal according to the encryption key. Encipherer **47B** outputs an encrypted data signal to data bus **24** via switch **43B** and I/O port **40B**.

Controller **134** reads and recognizes the address and retrieves the accompanying encryption key. Controller **134** provides the encryption key to decipherer **39**. The encrypted video data signal is retrieved from data bus **24** and supplied through I/O port **33** and switch **36** to decipherer **39**. Decipherer **39** decrypts the encrypted signal according to the encryption key and supplies a decrypted video signal to

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decoder 37. Decoder 37 decodes the prerecorded video data signal and supplies the decoded signal to a video display (not shown). Receiver 25 thus decrypts and decodes video data reproduced by a peripheral device in which a key card having a correct security key is installed.

In each of the above modes, it is alternately contemplated that one or more of the I/O ports has a fixed and inflexible structure which prevents its manipulation by a connected controller. In each of the above modes, it is further alternately contemplated that an address and the encryption key are not transmitted prior to the transmission of encrypted video data, but rather that the encryption key is prestored in the device which retrieves the encrypted video data.

The signal processing and interchange of messages in receiver-initiated data transfers according to the embodiment of the invention shown in FIG. 5 are diagrammatically represented in FIGS. 6(a)–(d). In each of FIGS. 6(a)–(d), the time axis runs positive in the direction indicated by the arrow. Although not explicitly mentioned in the following discussion, it should be understood that each communication between devices, with the exception of encrypted video data, includes an address of the device to which the communication is being sent.

FIG. 6(a) illustrates the interaction between receiver 25 and device 26 of FIG. 5 when receiver 25 initiates video data recording. In FIG. 6(a) receiver 25 first issues a record command to device 26. Receiver 25 then processes the record command in conjunction with a security key retrieved from memory 35 to produce a KEYCMD signal. Device 26 receives the record command and similarly processes it in conjunction with a security key retrieved from card port 45A to produce an ACK signal. Device 26 then transmits the ACK signal to receiver 25. Receiver 25 compares the received ACK signal with the KEYCMD signal to determine if they are equal. Since a key card having a correct security key is not installed in device 26, the KEYCMD signal and the ACK signal are not equal. As a result, receiver 25 determines that the ACK signal is "no good" (NG) and no data is output by receiver 25.

In FIG. 6(b), receiver 25 transmits a record command to device 27. As in the manner previously described, both receiver 25 and device 27 process the recording command to produce, respectively, a KEYCMD signal and an ACK signal. Device 27 transmits the ACK signal to receiver 25. Receiver 25 compares the KEYCMD signal and the received ACK signal. Since device 27 is engaged with a key card having a correct security key, the ACK signal and the KEYCMD are equal. Receiver 25 determines that the ACK signal is thus "OK" and transmits an encryption key to device 27. Receiver 25 also sends encrypted video data to data bus 24. Device 27 retrieves, decrypts, and records the encrypted video data.

FIGS. 6(c) and 6(d) illustrate the sequence of steps which occur when receiver 25 issues a playback command to a peripheral device. In FIG. 6(c), receiver 25 transmits a playback command to device 26. Receiver 25 processes the playback command in conjunction with a security key retrieved from memory 35 to produce a KEYCMD signal. Device 26 processes the received playback command in conjunction with a security key retrieved from card port 45A to produce an ACK signal. Device 26 transmits the ACK signal to receiver 25. Receiver 25 compares the KEYCMD signal with the received ACK signal to determine if they are equal. Since a key card containing a correct security key is not installed in device 26, the ACK signal is not equal to the KEYCMD signal. Accordingly, receiver 25 determines that the ACK signal is "no good" (NG). Nonetheless, device 26 attempts to send an encryption key and encrypted reproduced video signal data to receiver 25 via data bus 24, but receiver 25 does not retrieve the key and the video data.

In FIG. 6(d), receiver 25 transmits a playback command to device 27. Receiver 25 process the playback command, as before, to produce a KEYCMD signal. Device 27 processes the received playback command in conjunction with a security key retrieved from card port 45B to produce an ACK signal. Device 27 transmits this ACK signal to receiver 25. Receiver 25 compares the KEYCMD signal to the received ACK signal to determine if they are equal. Since key card 48 is engaged in device 27 and key card 48 contains a valid security key, the ACK signal and the KEYCMD signal are equal. Accordingly, receiver 25 determines that the ACK signal is "OK". Device 27 reproduces a prerecorded video signal and transmits an encryption key and encrypted reproduced video data to receiver 25. Receiver 25 accepts the encryption key and retrieves the encrypted video data.

The signal processing and interchange of messaging in device-initiated data transfers according to the second embodiment of the invention are diagrammatically represented in FIGS. 7(a)–(d). In each of FIGS. 7(a)–(d), the time axis runs positive in the direction indicated by the arrow. Although not explicitly mentioned in the following discussion, it should be understood that each communication between devices, with the exception of encrypted video data, includes an address of the device to which the communication is being sent.

FIGS. 7(a) and 7(c) illustrate the interaction between device 26 and receiver 25 of FIG. 1 when device 26 initiates the transfer of video data. In FIG. 7(a), device 26 first issues a send data command to receiver 25. Device 26 then processes the send data command in conjunction with a security key retrieved from card port 45A to produced a KEYCMD signal. Receiver 25 receives the send data command and similarly processes it in conjunction with a security key retrieved from memory 35 to produce an ACK signal. Receiver 25 then transmits the ACK signal to device 26. Device 26 compares the received ACK signal with the KEYCMD signal to determine if they are equal. Since a key card having a correct security key is not installed in device 26, the KEYCMD signal and the ACK signal are not equal. As a result, device 26 determines that the ACK signal is "no good" (NG). Nonetheless, receiver 25 attempts to transmit an encryption key and encrypted broadcast video data to device 26 via data bus 24, but device 26 does not retrieve the encryption key nor the video data.

In FIG. 7(c), device 26 first transmits a receive data command to receive 25. Device 26 then processes the receive data command in conjunction with a security key retrieved from card port 45A to produce a KEYCMD signal. Receiver 25 receives the receive data command and similarly processes it in conjunction with a security key retrieved from memory 35 to produce an ACK signal. Receiver 25 then transmits the ACK signal to device 26. Device 26 compares the received ACK signal with the KEYCMD signal to determine if they are equal. Since a key card having a correct security key is not installed in device 26, the KEYCMD signal and the ACK signal are not equal. As a result, device 26 determines that the ACK signal is "no good" (NG) and no data is output by device 26.

Each of FIGS. 7(b) and 7(d) illustrates the sequence of operations that occur when device 27 issues a command to receiver 25. In FIG. 7(b), device 27 first transmits a send data command to receiver 25. Device 27 processes the send data

command in conjunction with a security key retrieved from card port 45B to produce a KEYCMD signal. Receiver 25 processes the send data command in conjunction with a security key retrieved from memory 35 to produce an ACK signal. Receiver 25 then transmits the ACK signal to device 27. Device 27 compares the KEYCMD signal with the received ACK signal to determine if they are equal. Since key card 48 is engaged in device 27 and key card 48 contains a correct security key, the ACK signal and the KEYCMD signal are equal. Accordingly, device 27 determines that the ACK signal is "OK". Receiver 25 transmits an encryption key and encrypted video data to device 27 which decrypts and records the video data.

In FIG. 7(d), device 27 first transmits a receive data command to receiver 25. Device 27 processes the receive data command in conjunction with a security key retrieved from card port 45B to produce a KEYCMD signal. Receiver 25 processes the receive data command in conjunction with a security key retrieved from memory 35 to produce an ACK signal. Receiver 25 transmits the ACK signal to device 27. Device 27 compares the KEYCMD signal with the received ACK signal to determine if they are equal. Since key card 48 is engaged in device 27 and key card 48 contains a correct security key, the ACK signal and the KEYCMD signal are equal. Accordingly, device 27 determines that the ACK signal is "OK". Device 27 reproduces and encrypts a prerecorded video signal and transmits the encryption key and the encrypted reproduced video data to receiver 25. Receiver 25 accepts, decrypts, and further processes the video data as described above.

In an encrypt/decrypt dubbing mode, encrypted data is communicated between two peripheral devices, such as the devices 26 and 27, each installed with a key card having the same security key. A master of such peripheral devices initiates a video data transfer by transmitting to data bus 24 an address of a slave among the peripheral devices along with a record command or a playback command. As described in the preceding, the slave device reads and recognizes the address, configures itself according to the command, and returns an address and an ACK signal.

As also described in the preceding, the master device reads and recognizes the address and processes the ACK signal to determine its validity. If the ACK signal is "OK" then a data transfer according to the command is executed; otherwise, no data transfer occurs. As part of a data transfer, the transmitting device reproduces and encrypts, according to an encryption key, prerecorded data. The encryption key is sent with the address of the receiving peripheral device to data bus 24. The other receiving peripheral device reads and recognizes the address and retrieves the encryption key. The transmitting device sends the encrypted data to data bus 24 and the receiving device retrieves, decrypts, and records the encrypted data.

The communication protocol of the apparatus of FIG. 5 is summarized in the flow diagram of FIG. 8. For ease of explanation, the term "Master" is employed to indicate the device which initiates a data transfer. The term "Slave" is employed to indicate the device which is addressed by the Master.

In step S7, the Master transmits an address of the Slave and a command to data bus 24. In step S8, the Slave receives the command and the Master and the Slave separately process the command in accordance with security key data obtained locally. The Master device produces a KEYCMD signal as a function of the command and its security key. The Slave produces an ACK signal as a function of the received command and its security key.

In step S9, the Slave transmits an address of the Master and the ACK signal to data bus 24. In step S10, the Master receives the ACK signal and determines whether the ACK signal is equal to the KEYCMD signal. If the two signals are not equal, then processing follows step S11; otherwise, processing follows step S12. In step S11, the Master inhibits or simply does not execute a video data transfer between the Master and the Slave. In step S12, the Master executes a video data transfer by transmitting an encryption key and encrypted video data to the Slave, or by receiving and retrieving an encryption key and encrypted video data transmitted by the Slave.

FIG. 9 illustrates a display device 28-1 suitable for connection to data bus 24 of the first embodiment of the invention described above with reference to FIG. 1. Display device 28-1 is comprised of a cathode-ray tube (CRT) 60, a signal processor 59, a decoder 58, a descrambler 57, a memory 56, a controller 55A, a switch 54, a tuner 53, a digital tuner 52, a switch 51, and an I/O port 59. CRT 60 and signal processor 59 are conventional devices which together comprise a conventional display apparatus. Tuner 53 is a conventional broadcast tuner which receives an unscrambled video signal. Tuner 52 is a satellite digital signal tuner which receives scrambled video data signals. Tuner 53, tuner 52 and switch 51 are coupled to inputs of switch 54 and each provides a respective video signal thereto.

I/O port 50 is coupled to data bus 24 (not shown), switch 51, and controller 55A. I/O port 50 routes data signals to switch 51 and routes address, control and data signals to controller 55A. Controller 55A is further coupled to switch 51, memory 56, switch 54, descrambler 57 and decoder 58. Memory 56 stores one or more security keys which controller 55A retrieves as needed. Controller 55A controls the state of switches 54 and 51 with switch control signals. Controller 55A can also enable or disable the operations of decoder 58 and descrambler 57.

Descrambler 57 is further coupled to the output of switch 54 and the input of decoder 58. When enabled by controller 55A, descrambler 57 descrambles video data and supplies unscrambled video data to decoder 58. When disabled by controller 55A, descrambler 57 passes video signals from switch 54 to decoder 58.

Decoder 58 is further coupled to the input of signal processor 59. When enabled by controller 55A, decoder 58 decodes video data and supplies decoded video data to signal processor 59. When disabled by controller 55A, decoder 58 passes video signals from descrambler 57 to signal processor 59.

Display device 28-1 has three modes of operation. In the first mode, controller 55A causes switch 54 to link tuner 53 with descrambler 57. Controller 55A disables descrambler 57 and decoder 58, allowing signal processor 59 and CRT 60 to display ordinary video data received by tuner 53.

In the second mode, controller 55A causes switch 54 to link tuner 52 with descrambler 57. Controller 57 enables descrambler 57 and decoder 58. Descrambler 57 descrambles a scrambled and coded video signal supplied by tuner 52 and supplies an unscrambled, though still coded, video signal to decoder 58. Decoder 58 decodes the coded signal and provides an uncoded video signal to signal processor 59 for display.

In the third mode, controller 55A reads an address signal on data bus 24 through I/O port 50. If the address corresponds to an address previously assigned to device 28-1, then controller 55A recognizes the address as such and processing proceeds as follows. Controller 55A retrieves a dis-

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play command from data bus **24**. Controller **55A** generates an ACK signal as a function of the display command and a security key retrieved from memory **56**. Controller transmits an address of the device which sent the display command along with the ACK signal to data bus **24** through I/O port **50**. Controller **55A** also causes switch **51** to close, connecting I/O port **50** with switch **54**, and causes switch **54** to connect switch **51** with descrambler **57**. Controller **55A** also enables descrambler **57** and decoder **58**.

Controller **55A** monitors data bus **24** for another address signal corresponding to device **28-1**. Upon receipt of such an address, video data is then retrieved from data bus **24** and supplied through I/O port **50**, switch **51**, and switch **54** to descrambler **57**. Descrambler **57** descrambles, as needed, the retrieved video data and provides an unscrambled video signal to decoder **58**. Decoder **58** decodes the signal and supplies an uncoded video signal to signal processor **59** for display on CRT **60**.

FIG. **10** illustrates a decoding device **29-1** suitable for connection to data bus **24** of the first embodiment of the invention in place of the receiver **21**. Decoding device **29-1** is comprised of a memory **72**, a controller **71A**, an I/O port **70**, a switch **73**, and a decoder **74**. Decoder **74** and switch **73** have the same structure and function as their counterparts decoder **37** and switch **36** of receiver **21**. Controller **71A** is coupled to memory **72**, I/O port **70**, and switch **73**. Switch **73** is further connected to decoder **74** and I/O port **70**. I/O port **70** is further coupled to data bus **24**.

As in the processing described above, controller **71A** monitors data bus **24** for an address signal of device **29-1**. Upon recognizing such an address signal, controller **71A** retrieves a display command from data bus **24** and generates an ACK signal as a function of the display command and a security key retrieved from memory **72**. The ACK signal is transmitted with the appropriate address to data bus **24**. Video data accompanied by an address of device **29-1** is retrieved and routed through I/O port **70** and switch **73** to decoder **74**. Decoder **74** decodes the video signal and provides an uncoded video signal to a display (not shown).

As earlier noted, FIG. **11** illustrates a display device **28-2** suitable for connection to data bus **24** of the second embodiment of the invention. Display device **28-2** is comprised of the elements described above in connection with the display device **28-1**, and which are interconnected and function in the same manner as in display device **28-1** except as described in the following. Unlike display device **28-1**, display device **28-2** includes a decipherer **61** interposed between switch **51** and switch **54** and controller **55A** is replaced by controller **55B**. Controller **55B** is additionally coupled to decipherer **61** and supplies an encryption key thereto. Decipherer **61** decrypts encrypted video data supplied from switch **51** and supplies decrypted video data to switch **54**.

In accordance with the protocol of the second embodiment, controller **55B** monitors data bus **24** for an address of device **28-2** and an accompanying display command. An ACK signal is generated as a function of the retrieved display command a security key retrieved from memory **56**. Controller **55B** then transmits an appropriate address and the ACK signal to data bus **24**. Controller **55B** monitors data bus **24** for the address of device **28-2** and an accompanying encryption key. Upon receipt, decipherer **51** is supplied with the encryption key, and I/O port **50** and switch **51** are configured to route encrypted data through to decipherer **61**. Decipherer **61** decrypts the video data and supplies a decrypted signal suitable for subsequent processing as described with respect to device **28-1**.

FIG. **12** illustrates a decoding device **29-2** suitable for connection to data bus **24** in place of the receiver **25** in the second embodiment of the invention. Decoding device **29-2** is comprised of the same elements as decoding device **29-1**, and such elements are interconnected and function in the same manner as in decoding device **29-1** except as described in the following. Unlike decoding device **29-1**, decoding device **29-2** includes a decipherer **76** interposed between switch **73** and decoder **74**, and controller **71A** is replaced by controller **71B**. Controller **71B** is additionally coupled to decipherer **76** and supplies an encryption key thereto. Decipherer **76** decrypts encrypted video data supplied from switch **73** and supplies decrypted video data to decoder **74**.

As described in the process above, controller **71B** monitors data bus **24** for an address signal of device **29-2**. Upon recognizing such an address signal, controller **71B** retrieves a display command from data bus **24** and generates an ACK signal as a function of the display command and a security key retrieved from memory **72**. The ACK signal is transmitted with the appropriate address to data bus **24**. An encryption key accompanied by an address of device **29-2** is retrieved by controller **71B** from data bus **24**. Encrypted video data supplied from data bus **24** is routed through I/O port **70** and switch **73** to decipherer **76**. Decipherer **76** decrypts the encrypted video data and provides a decrypted video signal to decoder **74**. Decoder **74** decodes the decrypted video signal and provides an uncoded video signal to a display (not shown).

Although illustrative embodiments of the present invention and modifications thereof have been described in detail herein, it is to be understood that this invention is not limited to these precise embodiments and modifications, and that other modifications and variations may be effected therein by one skilled in the art without departing from the scope and spirit of the invention as defined by the appended claims.

What is claimed is:

[1. A method for communicating video data via a data bus between a master device and a slave device which are each coupled to said bus, comprising the steps of:

transmitting from said master device to said data bus a slave address of said slave device and a command;

generating, at said master device, a KEYCMD signal as a function of said command and a master security key;

receiving, at said slave device from said data bus, said slave address and said command and recognizing said slave address as corresponding to said slave device;

generating, at said slave device, an ACK signal as a function of said command and a slave security key;

transmitting from said slave device to said data bus a master address of said master device and said ACK signal;

receiving, at said master device from said data bus, said master address and said ACK signal and recognizing said master address as corresponding to said master device;

comparing said KEYCMD signal generated by said master device with said ACK signal received by said master device; and

executing a data transfer between said master device and said slave device if said KEYCMD signal corresponds to said ACK signal.]

[2. The method, according to claim 1, further comprising the step of:

inhibiting a data transfer between said master device and said slave device if said KEYCMD signal does not correspond to said ACK signal.]

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[3. The method, according to claim 2, wherein said data is unencrypted and encoded and wherein said step of inhibiting a data transfer comprises:

transmitting said data from said slave device to said data bus; and

preventing said master device from decoding said data from said data bus.]

[4. The method, according to claim 2, wherein said step of inhibiting a data transfer comprises:

preventing said master device from transmitting said data to said data bus.]

[5. The method, according to claim 1, wherein said master device is a receiver and said slave device is a peripheral device.]

[6. The method, according to claim 5, wherein said peripheral device is a display device.]

[7. The method, according to claim 1, wherein said master device is a peripheral device and said slave device is a receiver.]

[8. The method, according to claim 1, wherein said master device is a first peripheral device and said slave device is a second peripheral device.]

[9. The method, according to claim 1, wherein said slave device comprises means for decoding an unencrypted coded data.]

[10. The method, according to claim 1, wherein said step of executing a data transfer comprises:

encrypting said data in said master device according to an encryption key; and

decrypting said data in said slave device according to said encryption key.]

[11. The method, according to claim 10, wherein said step of executing a data transfer further comprises:

transmitting said slave address and said encryption key from said master device to said data bus; and

receiving said encryption key and said slave address at said slave device from said data bus and recognizing said slave address as corresponding to said slave device.]

[12. The method, according to claim 10, further comprising the step of:

inhibiting a data transfer between said master device and said slave device if said KEYCMD signal does not correspond to said ACK signal.]

[13. The method, according to claim 12, wherein said step of inhibiting a data transfer comprises:

preventing said master device from transmitting said data to said data bus.]

[14. The method, according to claim 10, wherein said master device is a receiver and said slave device is a peripheral device.]

[15. The method, according to claim 14, wherein said peripheral device is a display device.]

[16. The method, according to claim 10, wherein said master device is a peripheral device and said slave device is a receiver.]

[17. The method, according to claim 10, wherein said master device is a first peripheral device and said slave device is a second peripheral device.]

[18. The method, according to claim 10, wherein said slave device comprises means for decoding a decrypted coded data.]

[19. The method, according to claim 1, wherein said step of executing a data transfer comprises:

encrypting said data in said slave device according to an encryption key; and

decrypting said data in said master device according to said encryption key.]

[20. The method, according to claim 19, wherein said step of executing a data transfer further comprises:

transmitting said master address and said encryption key from said slave device to said data bus; and

receiving said master address and said encryption key from said data bus at said master device and recognizing said master address as corresponding to said master device.]

[21. The method, according to claim 19, further comprising the step of:

inhibiting a data transfer between said master device and said slave device if said KEYCMD signal does not correspond to said ACK signal.]

[22. The method, according to claim 21, wherein said data is encrypted and encoded and wherein said step of inhibiting a data transfer comprises:

transmitting said data from said slave device to said data bus; and

preventing said master device from decoding said data from said data bus.]

[23. The method, according to claim 19, wherein said master device is a receiver and said slave device is a peripheral device.]

[24. The method, according to claim 23, wherein said peripheral device is a display device.]

[25. The method, according to claim 19, wherein said master device is a peripheral device and said slave device is a receiver.]

[26. The method, according to claim 19, wherein said master device is a first peripheral device and said slave device is a second peripheral device.]

[27. The method, according to claim 19, wherein said slave device comprises means for decoding a decrypted coded data.]

[28. A system for communicating video data comprising:

at least one master device having a master address;

at least one slave device having a slave address;

a data bus, coupled to said master device and to said slave device;

said master device including:

means for transmitting to said data bus said slave address and a command,

means for generating a KEYCMD signal as a function of said command and a master security key,

means for receiving from said data bus said master address and an ACK signal,

means for recognizing said master address as corresponding to said master device,

means for comparing said KEYCMD signal and said ACK signal, and

means for receiving said video data from said data bus if said KEYCMD signal corresponds to said ACK signal; and

said slave device including:

means for receiving from said data bus said slave address and said command,

means for recognizing said slave address as corresponding to said slave device,

means for generating said ACK signal as a function of said command and a slave security key, and

means for transmitting to said data bus said master address, said ACK signal, and said video data.]

[29. The system according to claim 28, wherein said master device further comprises means for inhibiting reception

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of said video data from said data bus if said KEYCMD signal does not correspond to said ACK signal.]

[30. The system according to claim 29, wherein said means for inhibiting includes a switch.]

[31. The system according to claim 28, wherein said master device is a receiver and said slave device is a peripheral device.]

[32. The system according to claim 28, wherein said master device is a peripheral device and said slave device is a receiver.]

[33. The system according to claim 28, wherein said master device is a first peripheral device and said slave device is a second peripheral device.]

[34. The system according to claim 28, wherein said video data is unencrypted and encoded and wherein said slave device comprises means for decoding said video data.]

[35. The system according to claim 28, wherein:

said master device further includes means for decrypting said video data according to an encryption key; and

said slave device further includes means for encrypting said video data according to said encryption key.]

[36. The system according to claim 35, wherein:

said master device further includes means for receiving said encryption key from said data bus; and

said slave device further includes means for transmitting said encryption key to said data bus.]

[37. A system for communicating video data comprising:

at least one master device having a master address;

at least one slave device having a slave address;

a data bus, coupled to said master device and to said slave device;

said master device including:

means for transmitting to said data bus said slave address and a command,

means for generating a KEYCMD signal as a function of said command and a master security key,

means for receiving from said data bus said master address and an ACK signal,

means for recognizing said master address as corresponding to said master device,

means for comparing said KEYCMD signal and said ACK signal, and

means for transmitting to said data bus said video data if said KEYCMD signal corresponds to said ACK signal; and

said slave device including:

means for receiving from said data bus said slave address, said command and said video data,

means for recognizing said slave address as corresponding to said slave device,

means for generating said ACK signal as a function of said command and a slave security key; and

means for transmitting to said data bus said master address and said ACK signal.]

[38. The system according to claim 37, wherein said master device further includes means for inhibiting transmission of said video data to said data bus if said KEYCMD signal does not correspond to said ACK signal.]

[39. The system according to claim 37, wherein:

said master device further includes means for encrypting said video data according to an encryption key; and

said slave device further includes means for decrypting said video data according to said encryption key.]

[40. The system according to claim 39, wherein:

said master device further includes means for transmitting said encryption key to said data bus; and

said slave device further includes means for receiving said encryption key from said data bus.]

41. A display apparatus for displaying a video image, comprising:

a display device;

a communication interface locally connected to an external device for receiving encrypted digital video data;

a decryptor for decrypting said received encrypted digital video data;

a controller for executing an authentication procedure between said display apparatus and said external device and for controlling said decryptor; and

a switch for selecting either said digital video data received from said external device or another video signal to result in a display of a video image by said display device corresponding to the selection;

wherein said controller controls said decryptor to initiate said decrypting of said received encrypted digital video data if said received digital video data is selected for display and if said authentication procedure is successfully executed.

42. The display apparatus according to claim 41, wherein said received encrypted digital video data is digital video data which is reproduced from a recording medium and encrypted in said external device.

43. The display apparatus according to claim 41, wherein said other video signal is an output from a television tuner.

44. The display apparatus according to claim 43, wherein said television tuner receives a digital television broadcast signal.

45. The display apparatus according to claim 43, wherein said television tuner receives an analog television broadcast signal.

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US006778182B2

(12) **United States Patent**
Yamakawa

(10) **Patent No.:** **US 6,778,182 B2**
(45) **Date of Patent:** **Aug. 17, 2004**

(54) **DISPLAY DEVICE**

(75) Inventor: **Yoshifumi Yamakawa**, Kanagawa (JP)

(73) Assignee: **Sony Corporation**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 20 days.

(21) Appl. No.: **09/995,398**

(22) Filed: **Nov. 27, 2001**

(65) **Prior Publication Data**

US 2002/0033830 A1 Mar. 21, 2002

Related U.S. Application Data

(62) Division of application No. 09/262,105, filed on Mar. 4, 1999.

(30) **Foreign Application Priority Data**

Mar. 12, 1998 (JP) P10-061399
Feb. 3, 1999 (JP) P11-026514

(51) **Int. Cl.**[7] **G09G 5/02**; H04N 5/202; H04N 1/46

(52) **U.S. Cl.** **345/589**; 345/22; 348/674; 348/375; 358/516; 358/519

(58) **Field of Search** 345/589, 593, 345/597, 204, 22, 72, 83, 87; 348/514, 519–520, 527–528, 557, 560, 577, 582, 603, 612, 630, 638, 663, 674–677, 254–256; 382/162–167; 358/515, 516, 518, 519

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2002/0149598	A1	*	10/2002	Greier et al.	345/589

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Assistant Examiner—Wesner Sajous
(74) *Attorney, Agent, or Firm*—Sonnenschein Nath & Rosenthal LLP

(57) **ABSTRACT**

The display device is able to make an image of a dark scene to become easy to see without increasing a contrast. A composite video signal from an input terminal (**1**) is supplied to a separating circuit **2**, in which it is separated to provide a luminance signal and two color-difference signals. The luminance signal thus separated is supplied to a dynamic gamma circuit (**5**). In this dynamic gamma circuit (**5**), its gamma correction curve between an input and an output thereof is changed in response to a control signal from a control circuit (**11**) in such a manner that an intermediate signal level is increased from approximately a straight line, for example. Then, the luminance signal thus gamma-corrected and two color-difference signals are converted by a converting circuit (**6**) into three primary color signals, and supplied through respective A/D-converting circuits (**7R**, **7G**, **7B**) to a display means (**8**) such as a plasma display or the like. Also, the luminance signal from the separating circuit (**2**) is supplied through a comparing circuit (**9**) to an integrating circuit (**10**). A signal from this integrating circuit (**10**) is supplied to the control circuit (**11**), from which there is generated a control signal whose magnitude corresponds to an average luminance level.

6 Claims, 18 Drawing Sheets

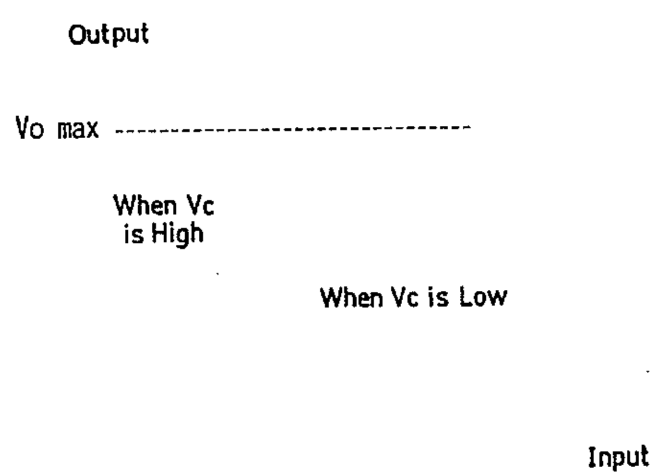

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FIG. 1

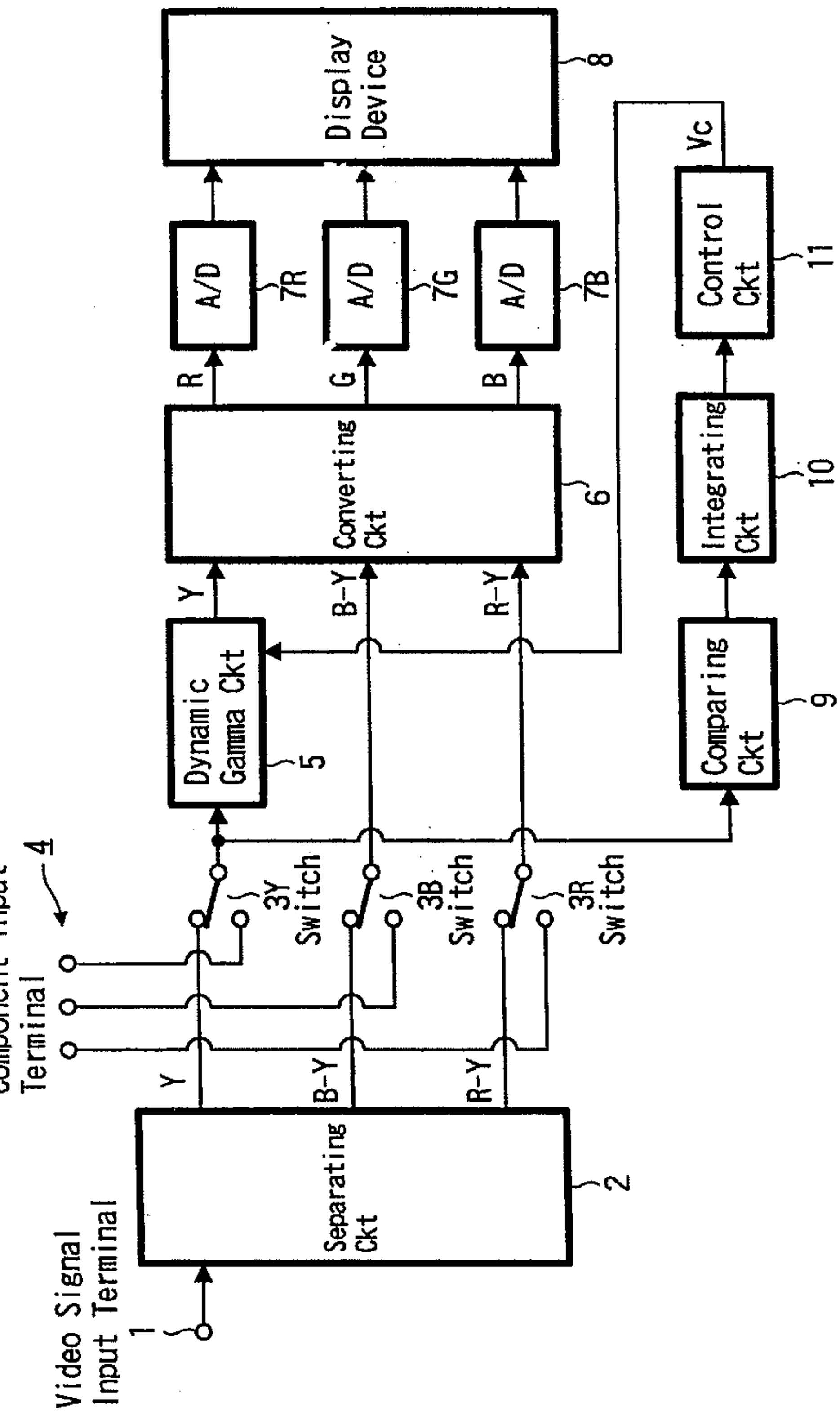

Video Signal Input Terminal
1
Separating Ckt
2
Y
B-Y
R-Y
Component Input Terminal
4
3Y Switch
3B Switch
3R Switch
Dynamic Gamma Ckt
5
Converting Ckt
6
Y
B-Y
R-Y
R
G
B
A/D
7R
7G
7B
Display Device
8
Comparing Ckt
9
Integrating Ckt
10
Control Ckt
11
Vc

FIG. 2

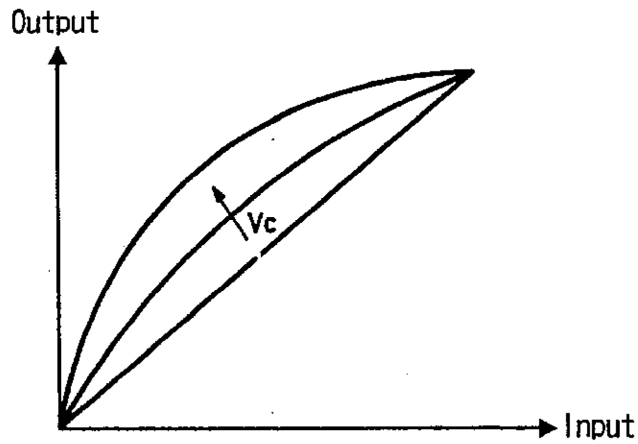

Output
Vc
Input

FIG. 3

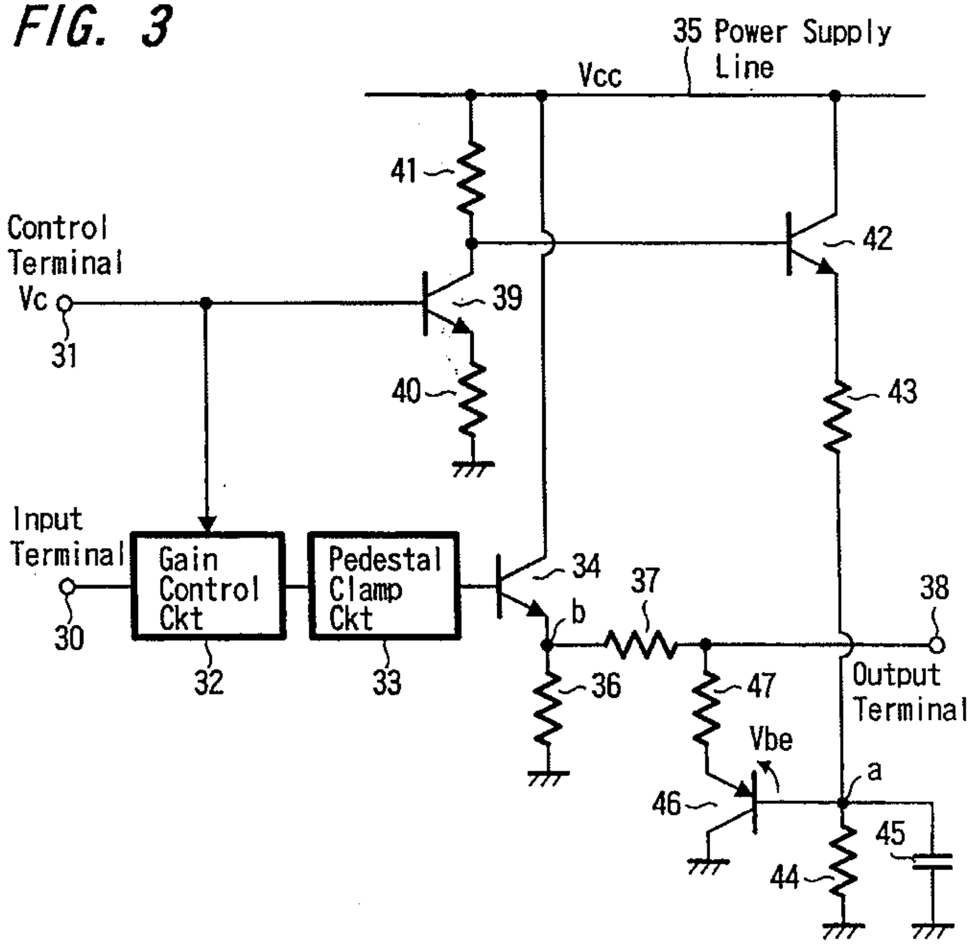
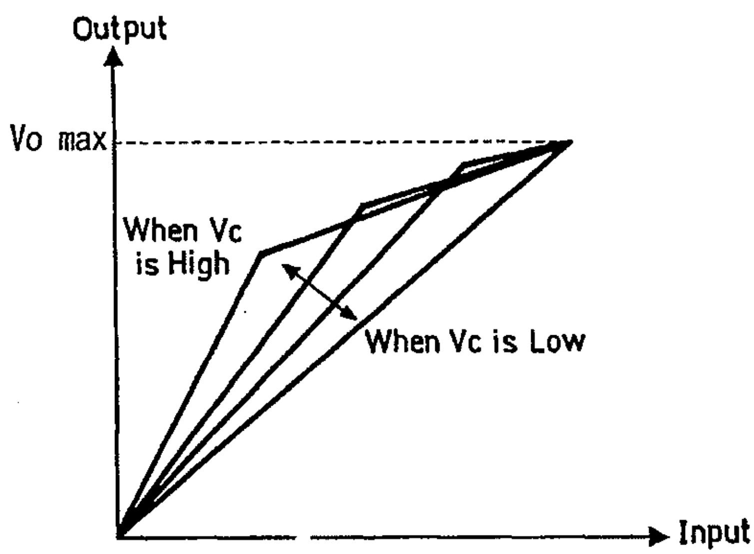

35 Power Supply Line
Vcc
41
42
Control Terminal
Vc
39
31
40
43
Input Terminal
Gain Control Ckt
Pedestal Clamp Ckt
34
37
38
30
b
32
33
36
47
Output Terminal
Vbe
a
46
45
44

FIG. 4



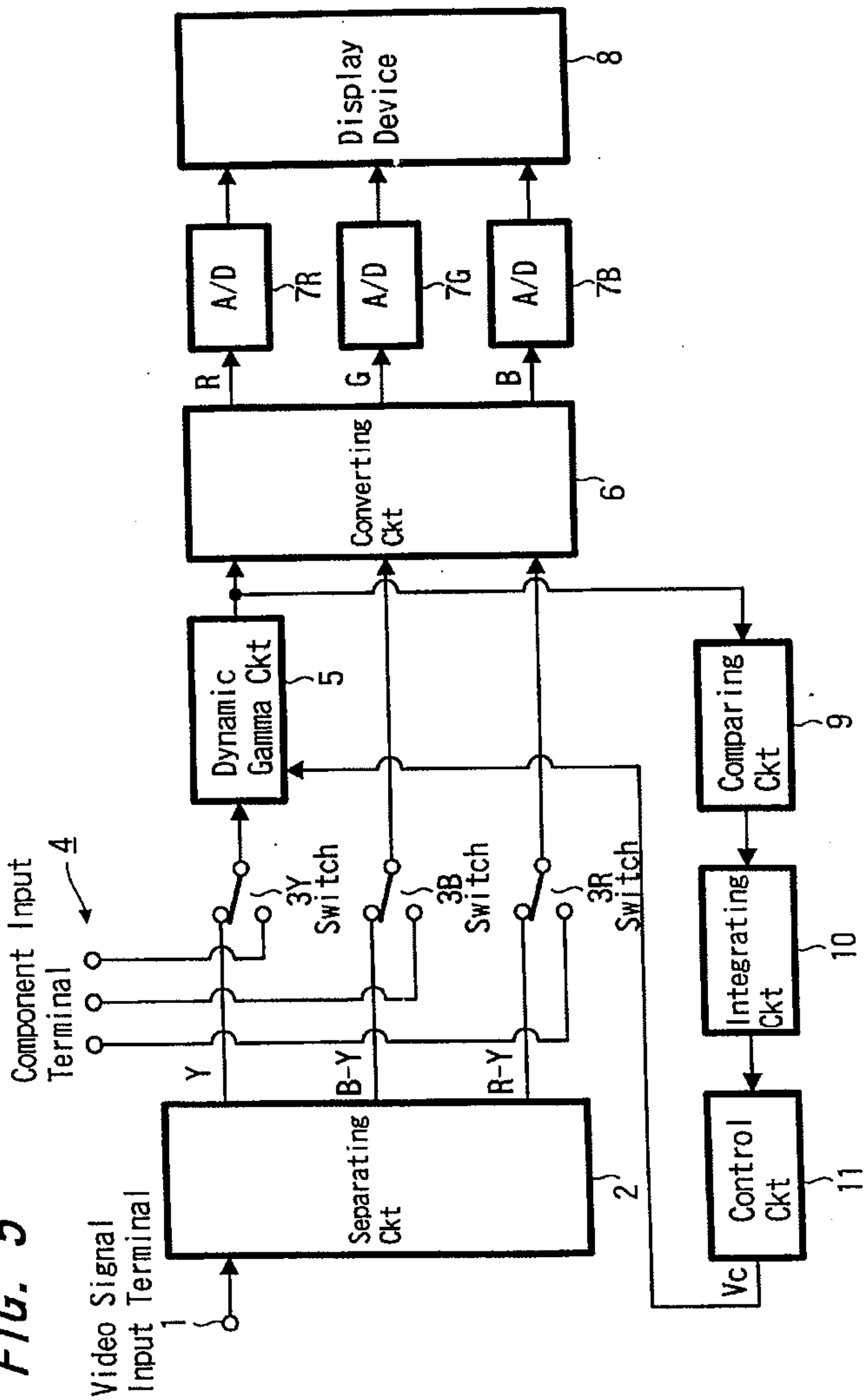


FIG. 5

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FIG. 6

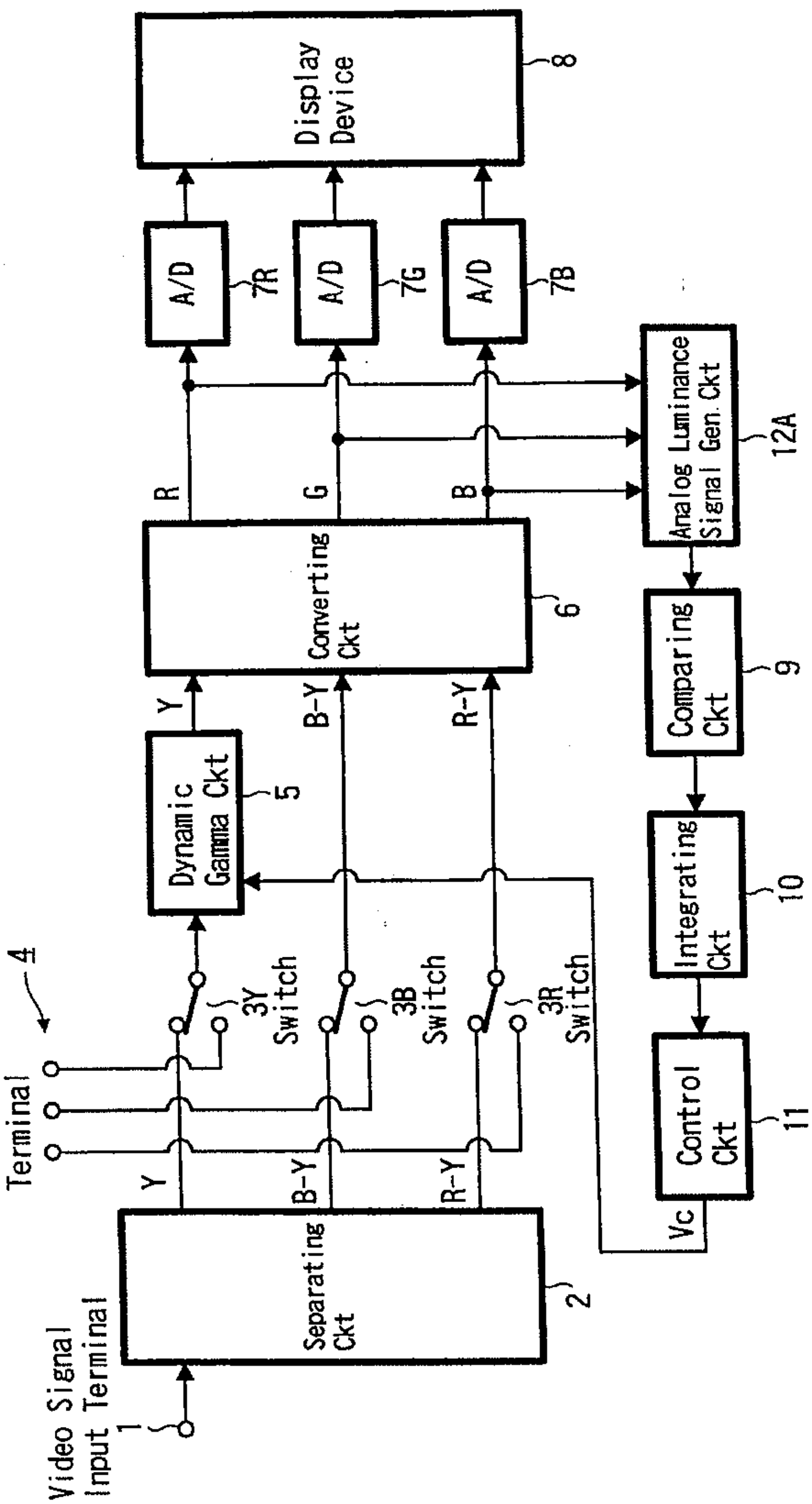
Display Device
8
A/D
7R
A/D
7G
A/D
7B
Analog Luminance Signal Gen. Ckt
12A
R
G
B
Converting Ckt
6
Comparing Ckt
9
Y
B-Y
R-Y
Dynamic Gamma Ckt
5
Integrating Ckt
10
Component Input Terminal
4
3Y Switch
3B Switch
3R Switch
Control Ckt
11
Y
B-Y
R-Y
Vc
Separating Ckt
2
Video Signal Input Terminal
1

FIG. 7

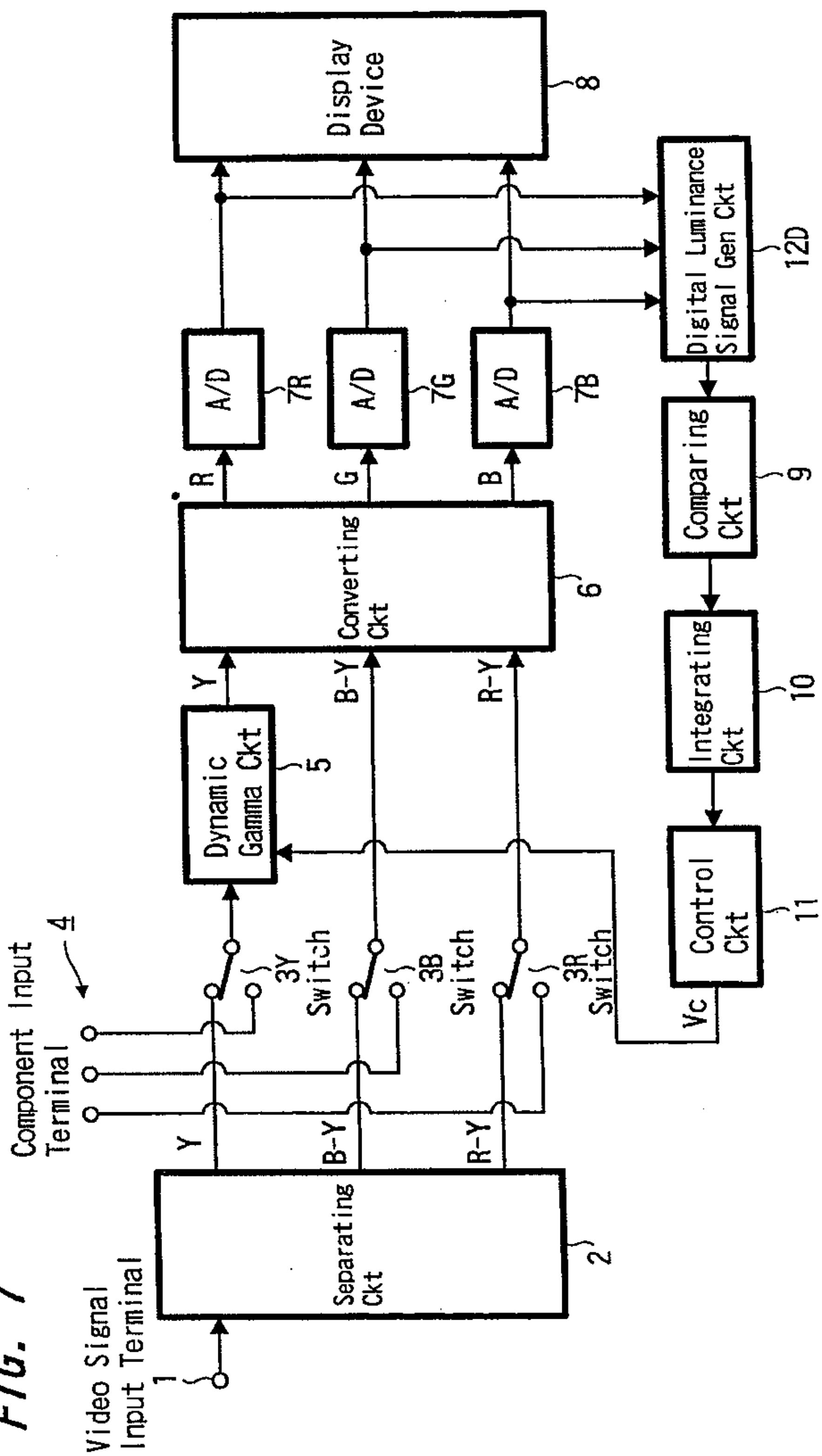

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FIG. 8

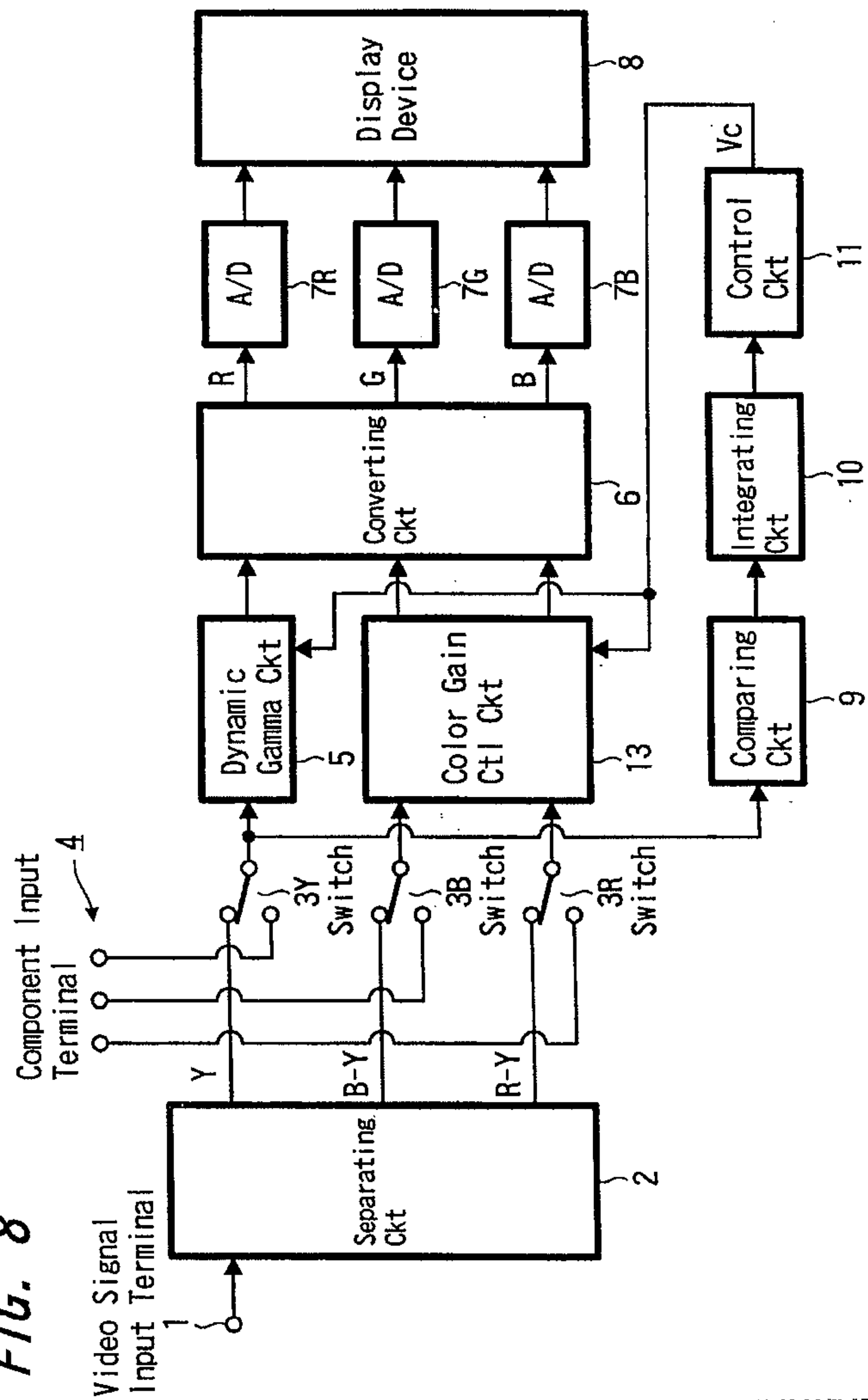

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FIG. 9

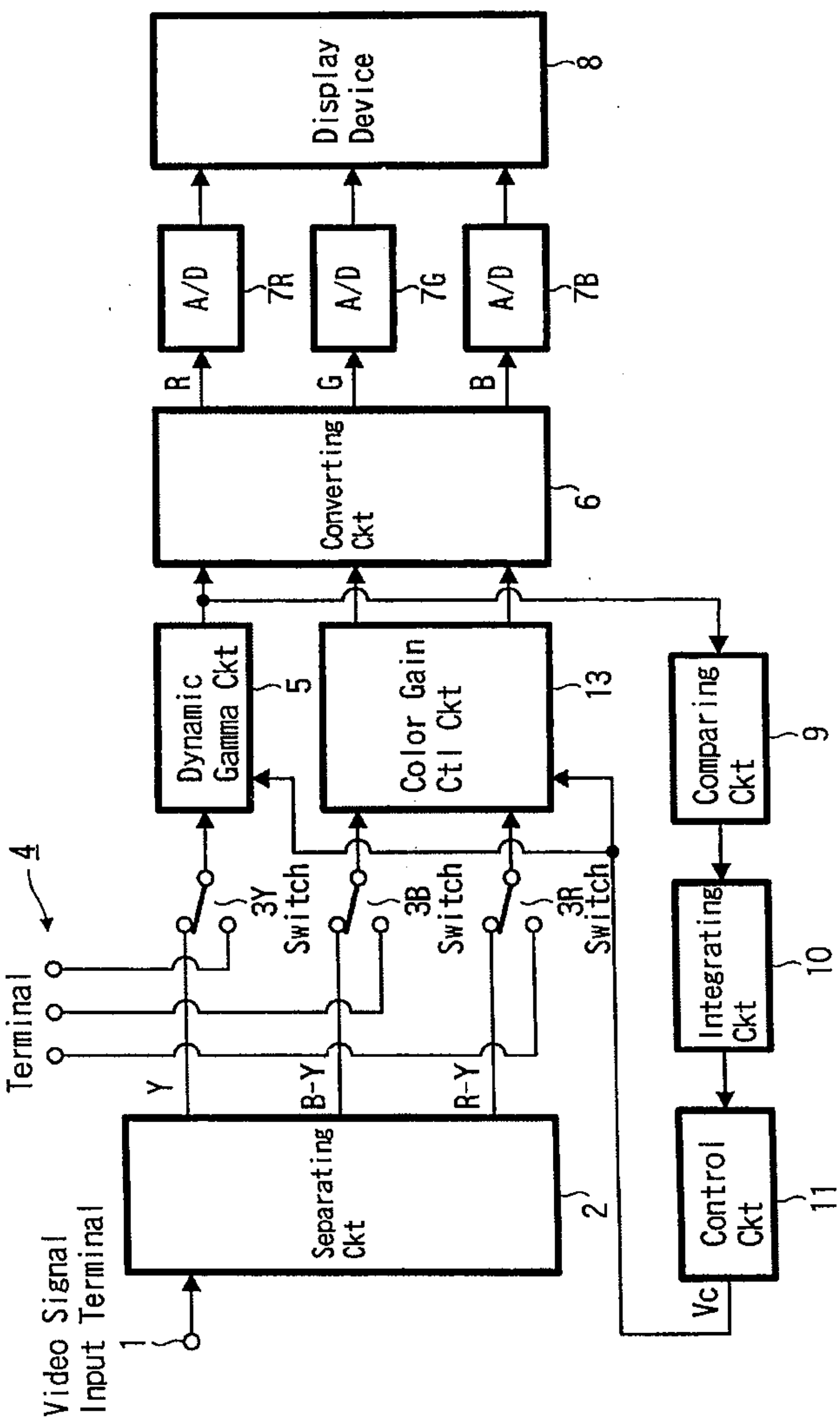

Video Signal Input Terminal
1
Separating Ckt
2
Y
B-Y
R-Y
Component Input Terminal
4
3Y Switch
3B Switch
3R Switch
Dynamic Gamma Ckt
5
Color Gain Ctl Ckt
13
Converting Ckt
6
R
G
B
A/D
7R
A/D
7G
A/D
7B
Display Device
8
Comparing Ckt
9
Integrating Ckt
10
Control Ckt
11
Vc

FIG. 10

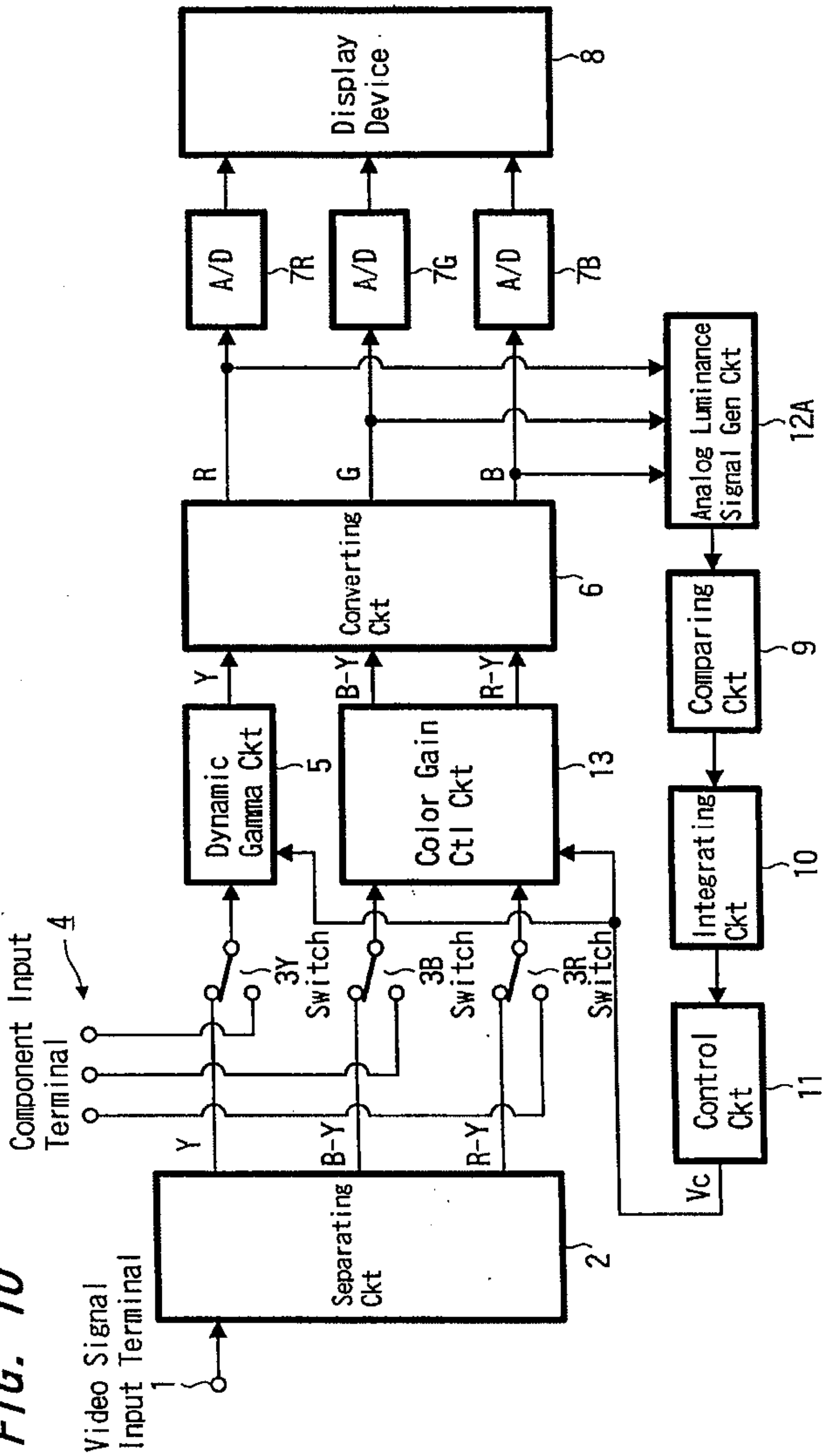

Display Device
8
A/D
7R
A/D
7G
A/D
7B
R
G
B
Analog Luminance Signal Gen Ckt
12A
Converting Ckt
6
Comparing Ckt
9
Y
B-Y
R-Y
Dynamic Gamma Ckt
5
Color Gain Ctl Ckt
13
Integrating Ckt
10
Component Input Terminal
4
3Y Switch
3B Switch
3R Switch
Control Ckt
11
Vc
Separating Ckt
2
Video Signal Input Terminal
1

FIG. 11

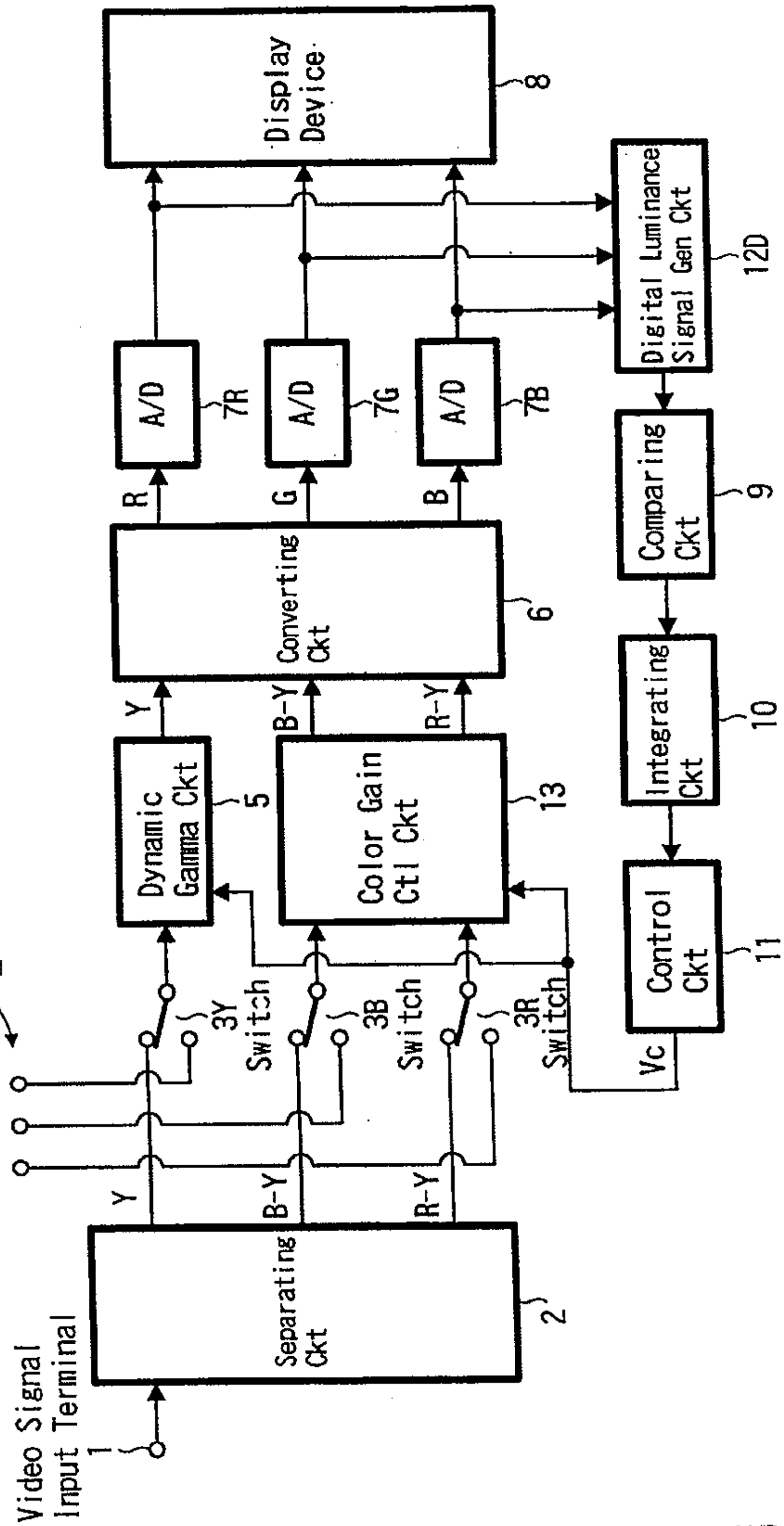

Display Device
8
Digital Luminance Signal Gen Ckt
12D
A/D
7R
A/D
7G
A/D
7B
Comparing Ckt
9
R
G
B
Converting Ckt
6
Integrating Ckt
10
Y
B-Y
R-Y
Dynamic Gamma Ckt
5
Color Gain Ctl Ckt
13
Control Ckt
11
Vc
Component Input Terminal
4
3Y Switch
3B Switch
3R Switch
Y
B-Y
R-Y
Separating Ckt
2
Video Signal Input Terminal
1

FIG. 12

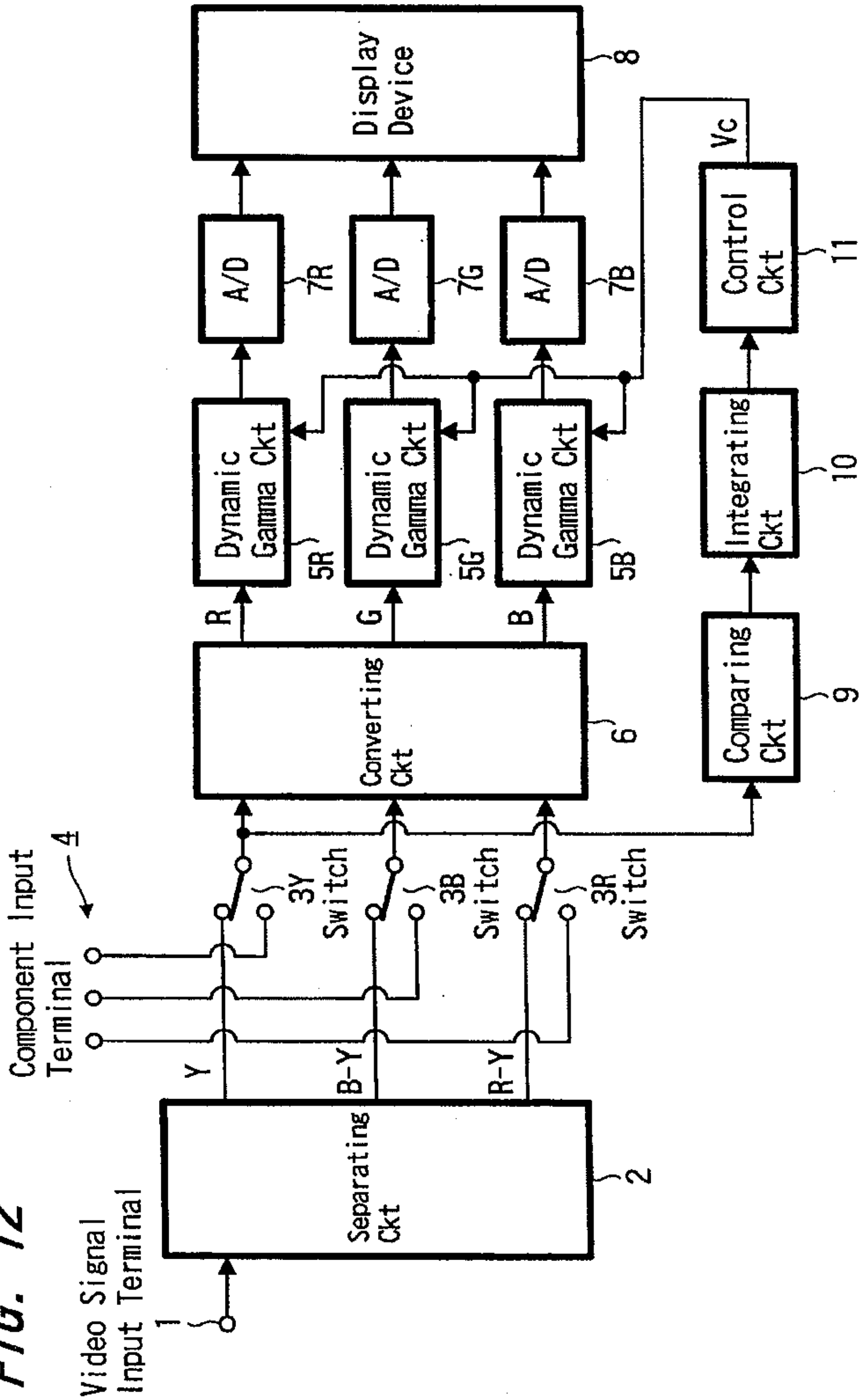
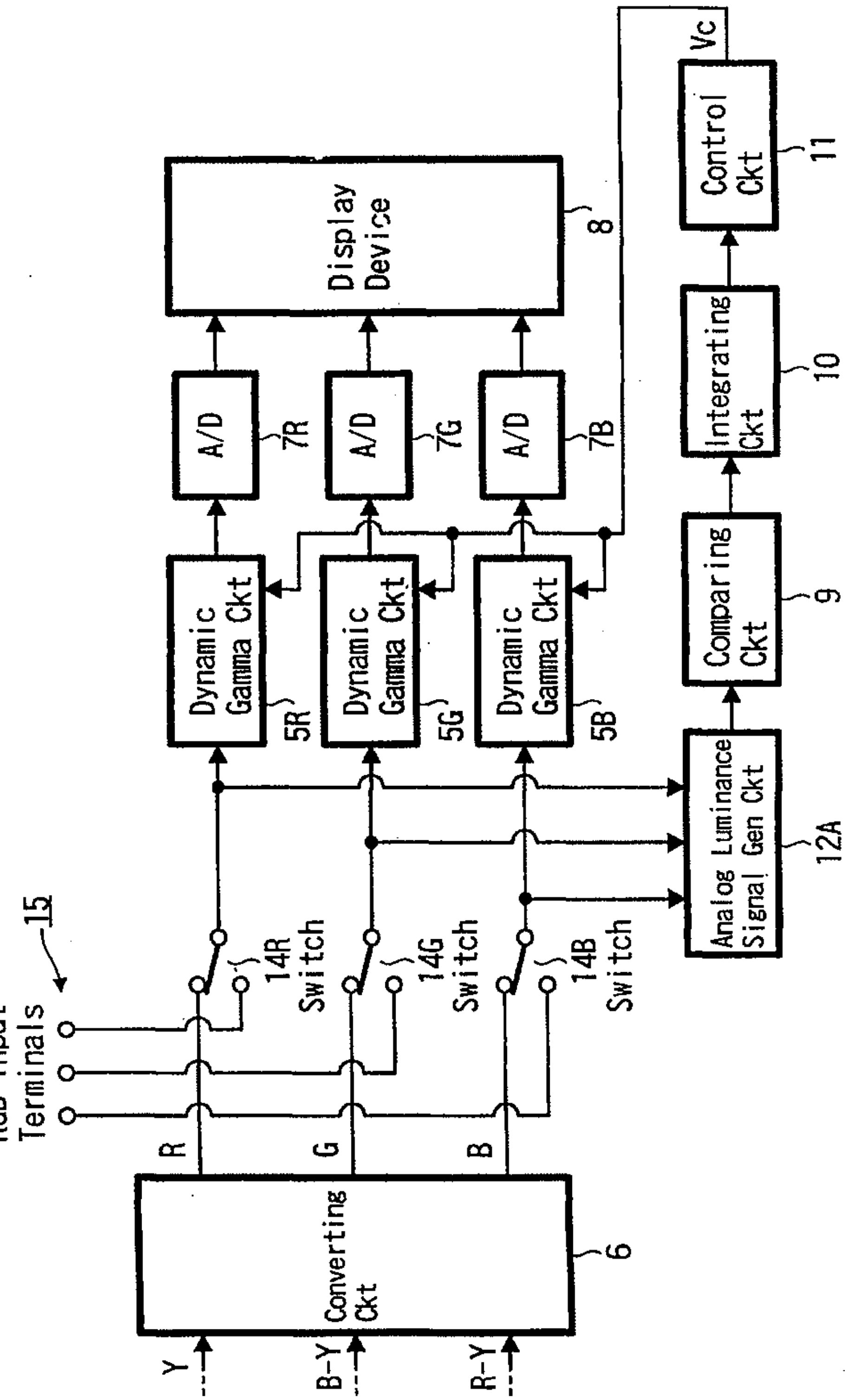
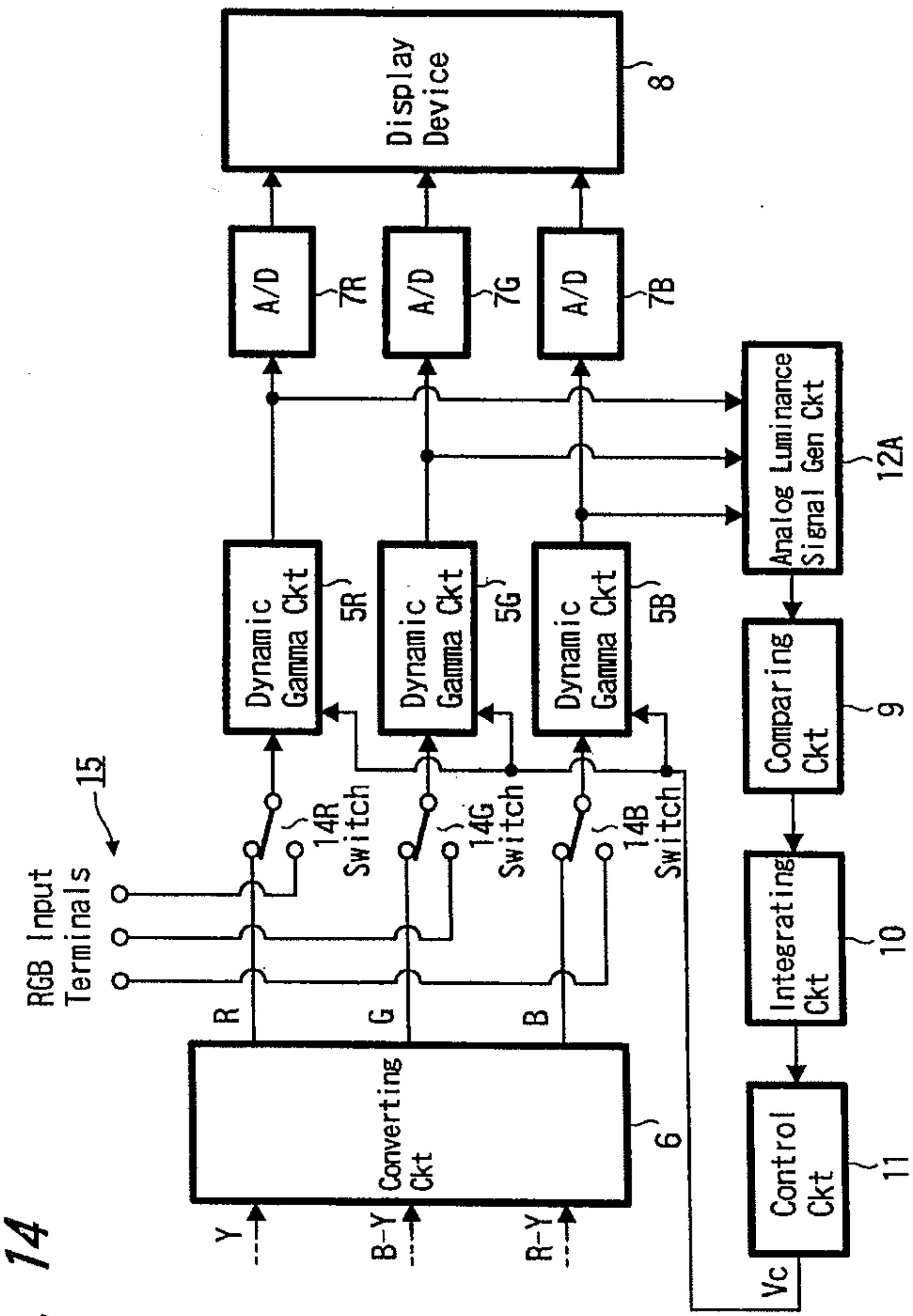

Display Device
8
A/D
7R
A/D
7G
A/D
7B
Vc
Control Ckt
11
Dynamic Gamma Ckt
5R
Dynamic Gamma Ckt
5G
Dynamic Gamma Ckt
5B
Integrating Ckt
10
R
G
B
Converting Ckt
6
Comparing Ckt
9
Component Input Terminal
4
3Y Switch
3B Switch
3R Switch
Y
B-Y
R-Y
Separating Ckt
2
Video Signal Input Terminal
1

FIG. 13



Y
B-Y
R-Y
Converting Ckt
6
R
G
B
RGB Input Terminals
15
14R Switch
14G Switch
14B Switch
Dynamic Gamma Ckt
5R
Dynamic Gamma Ckt
5G
Dynamic Gamma Ckt
5B
A/D
7R
A/D
7G
A/D
7B
Display Device
8
Analog Luminance Signal Gen Ckt
12A
Comparing Ckt
9
Integrating Ckt
10
Control Ckt
11
Vc

FIG. 14


Display Device
8
A/D
7R
A/D
7G
A/D
7B
Analog Luminance Signal Gen Ckt
12A
Dynamic Gamma Ckt
5R
Dynamic Gamma Ckt
5G
Dynamic Gamma Ckt
5B
Comparing Ckt
9
Integrating Ckt
10
Control Ckt
11
Vc
RGB Input Terminals
15
14R Switch
14G Switch
14B Switch
R
G
B
Converting Ckt
6
Y
B-Y
R-Y

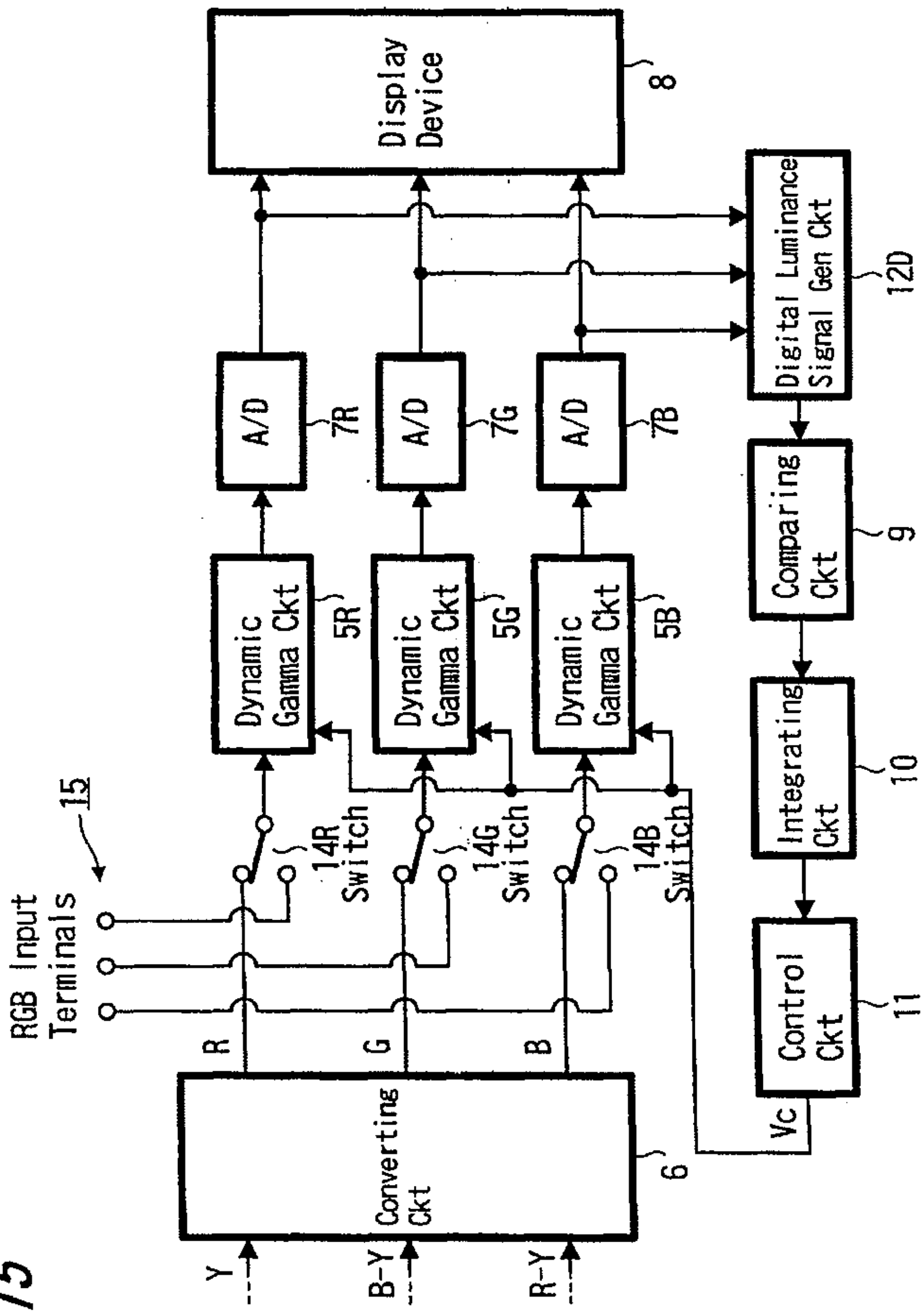

Display Device
8
Digital Luminance Signal Gen Ckt
12D
A/D
7R
A/D
7G
A/D
7B
Dynamic Gamma Ckt
5R
Dynamic Gamma Ckt
5G
Dynamic Gamma Ckt
5B
Comparing Ckt
9
Integrating Ckt
10
Control Ckt
11
Vc
14R Switch
14G Switch
14B Switch
RGB Input Terminals
15
R
G
B
Converting Ckt
6
Y
B-Y
R-Y

FIG. 15

FIG. 16

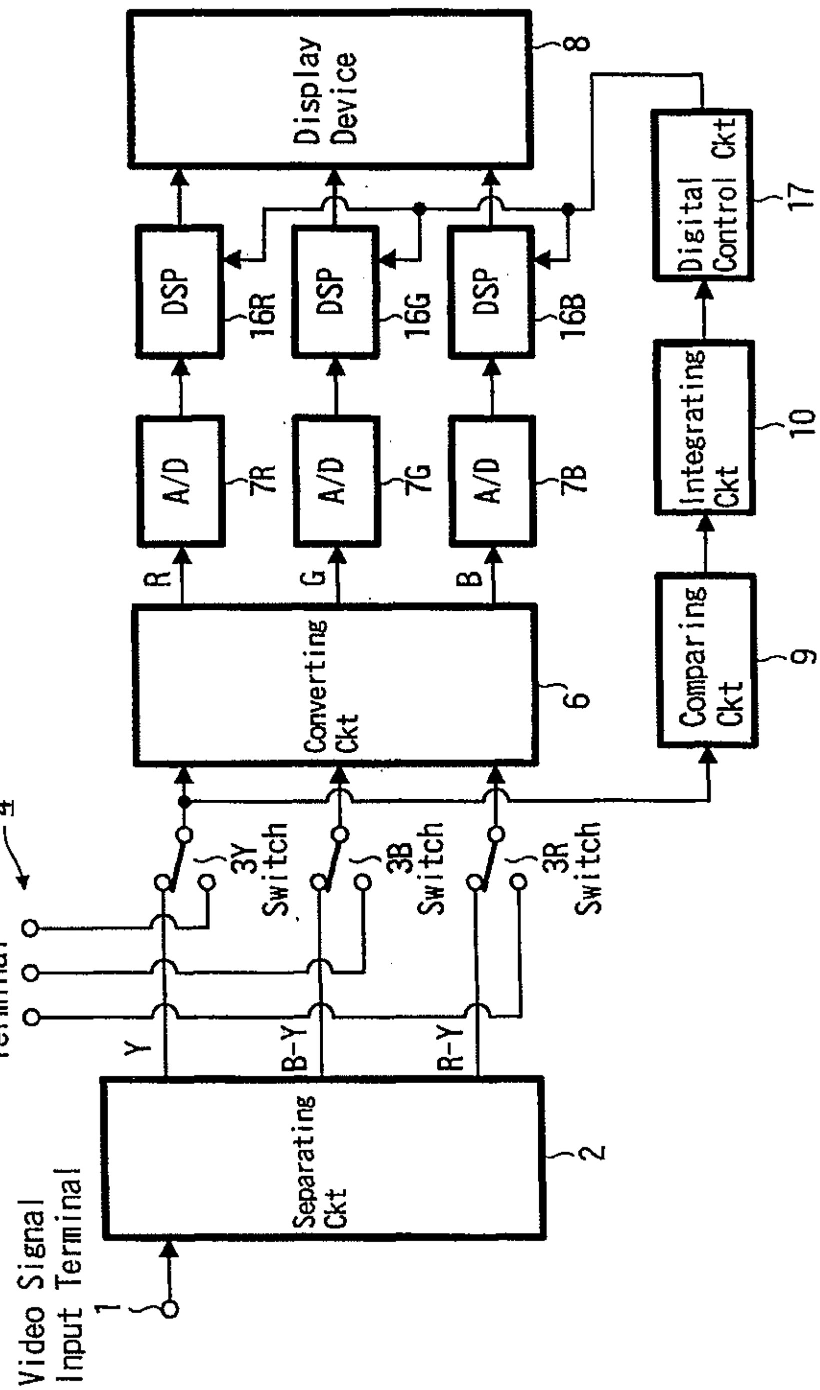


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FIG. 17

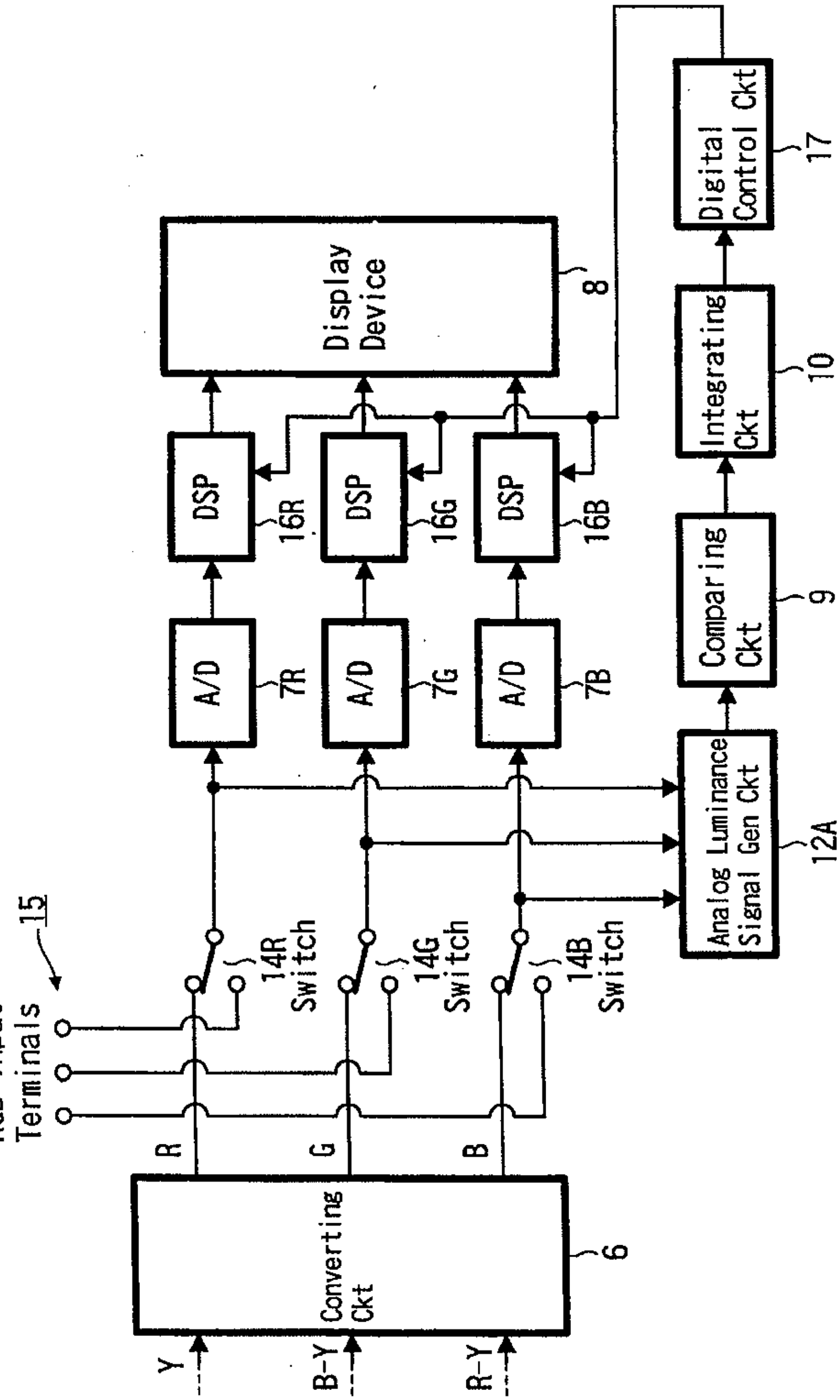

RGB Input Terminals
15
R
G
B
Y
B-Y
R-Y
Converting Ckt
6
14R Switch
14G Switch
14B Switch
A/D
7R
7G
7B
DSP
16R
16G
16B
Display Device
8
Analog Luminance Signal Gen Ckt
12A
Comparing Ckt
9
Integrating Ckt
10
Digital Control Ckt
17

FIG. 18

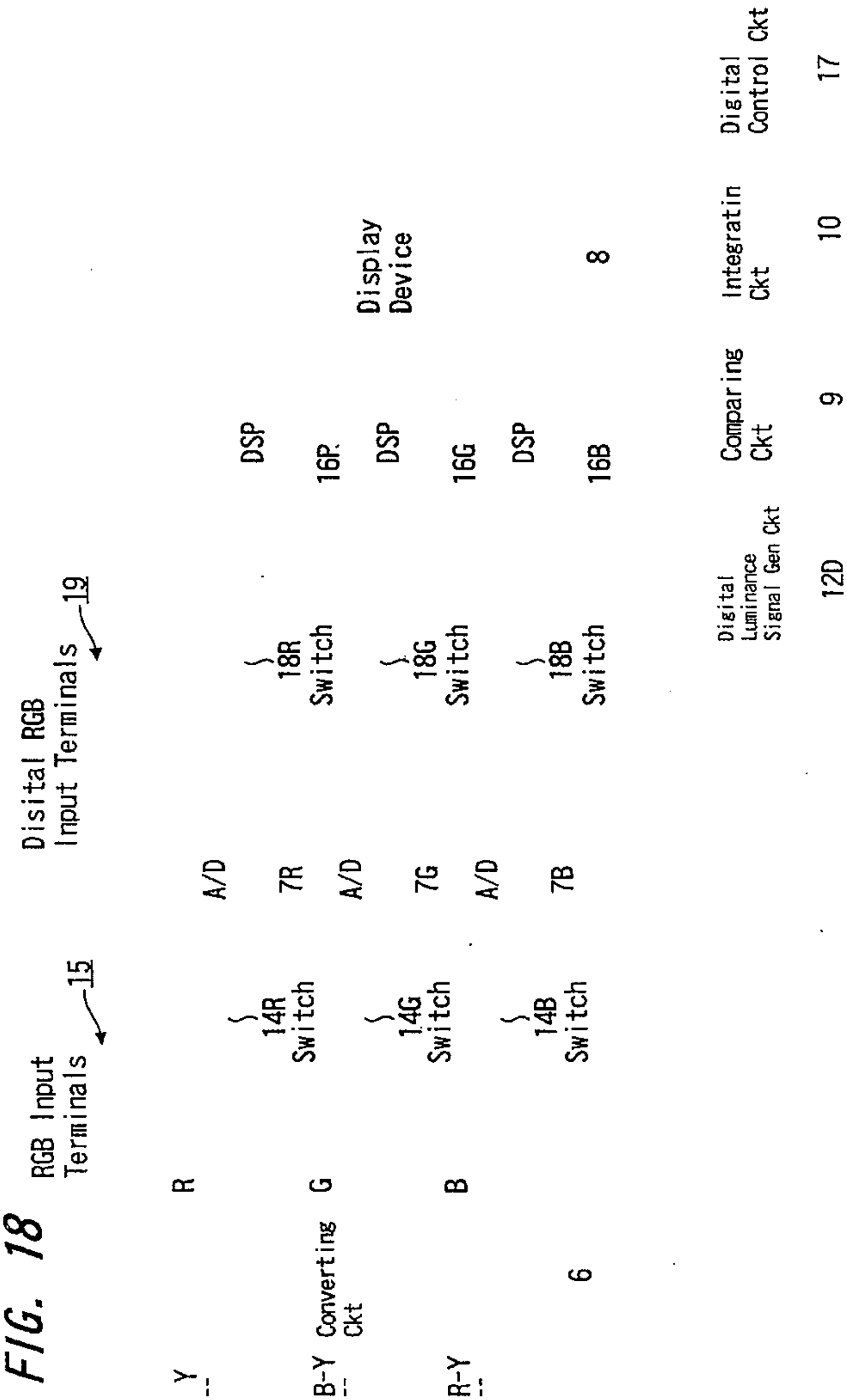
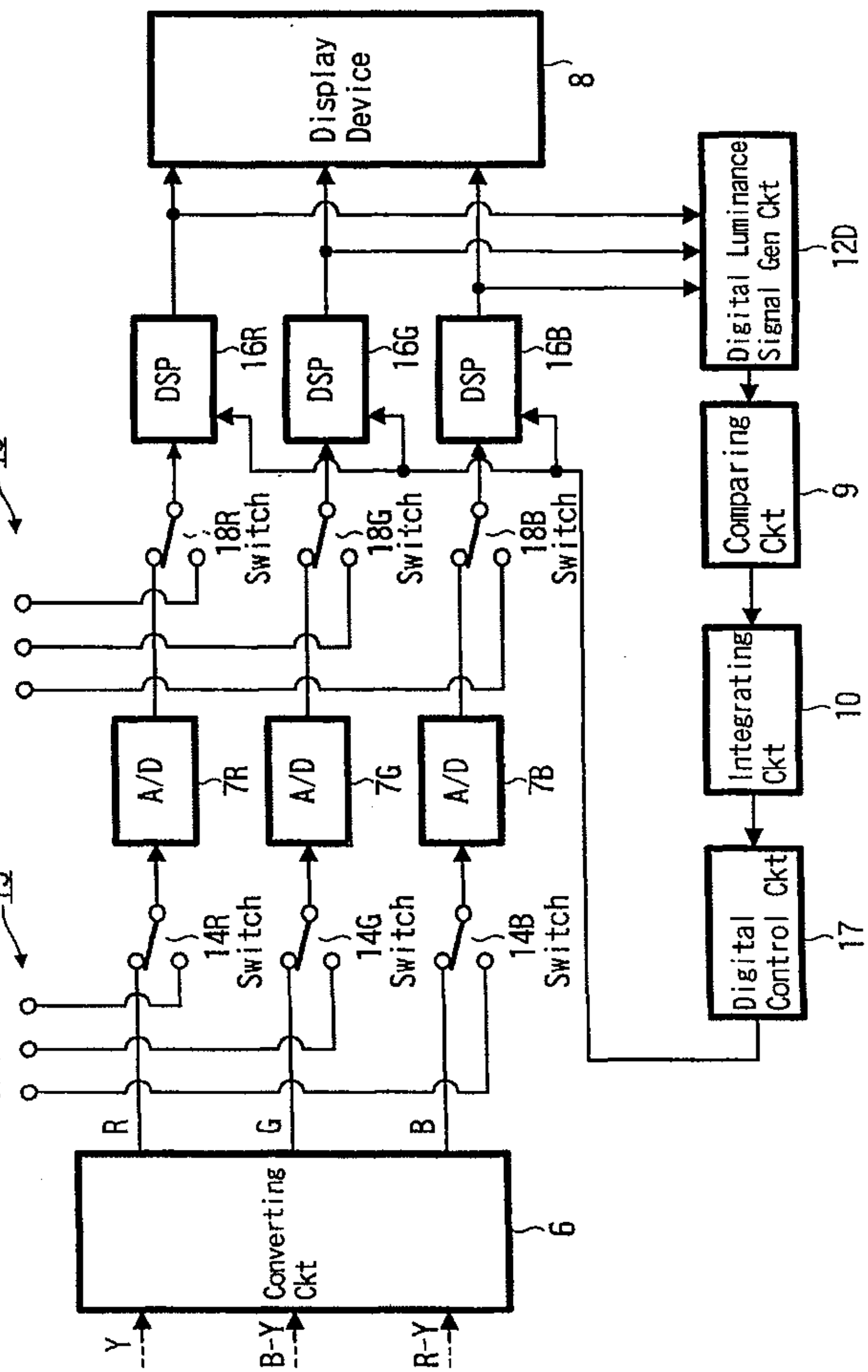

RGB Input Terminals
15
Disital RGB Input Terminals
19
Y
B-Y
R-Y
Converting Ckt
6
R
G
B
14R Switch
14G Switch
14B Switch
A/D
7R
7G
7B
18R Switch
18G Switch
18B Switch
DSP
16R
16G
16B
Display Device
8
Digital Luminance Signal Gen Ckt
12D
Comparing Ckt
9
Integratin Ckt
10
Digital Control Ckt
17

FIG. 19


Display Device
8
Digital Luminance Signal Gen Ckt
12D
DSP
16R
16G
16B
Comparing Ckt
9
Integrating Ckt
10
Digital Control Ckt
17
Disital RGB Input Terminals
19
18R Switch
18G Switch
18B Switch
A/D
7R
7G
7B
RGB Input Terminals
15
14R Switch
14G Switch
14B Switch
R
G
B
Converting Ckt
6
Y
B-Y
R-Y

DISPLAY DEVICE

The present application is a division of application Ser. No. 09/262,105, filed Mar. 4, 1999 and claims priority to Japanese Application No. P10-061399 filed Mar. 12, 1998 and Japanese Application No. P11-026514 filed Feb. 3, 1999 which applications are incorporated herein by reference to the extent permitted by law.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a display device for use in displaying an image by using a display means such as a plasma display, a liquid-crystal display or the like. More particularly, this invention relates to a display device in which the whole of an image may be made easy to see by increasing an intermediate luminance level while its maximum output is held at the constant level when an average luminance level of a displayed video signal is low.

2. Description of the Related Art

Heretofore, in display devices using a display means such as a plasma display and a liquid-crystal display, a contrast of a display image is lowered when a viewer watches the displayed image in the bright circumstances, for example. In particular, when a dark scene in which an object luminance level is low is displayed, a displayed image becomes difficult to see. Contrary to this device, display devices using, for example, a cathode-ray tube have hitherto been adapted to automatically increase a contrast of a displayed image (increase an amplitude of a video signal) when a study of measured results of an average luminance level of a video signal or the like reveals that its average luminance level is lowered.

In the display devices using the plasma display or the liquid-crystal display, for example, since a dynamic range of a luminance signal of these display devices is narrow, in order to effectively utilize this narrow dynamic range, it is customary that a margin of contrast is almost removed so that the maximum value of the amplitude of the ordinary video signal is already set to the limit of the dynamic range. There is then the risk that when a contrast is increased more than that, a white peal, for example, will be over the dynamic range and will be saturated.

In a scene in which only one portion is bright in the whole of a dark object, for example, when the whole contrast is increased based on the measured results of the average luminance level, there is then the risk that the signal level of the bright portion will be over the dynamic range. As a consequence, in such scene, the video signal of the above-mentioned bright portion will be saturated to cause a so-called white compression. There is then the problem that a gradation of this bright portion cannot be expressed.

The problems that the present invention intends to solve are that an image becomes difficult to see in the scene in which the object luminance level is low and that when the whole contrast is increased, in the scene in which only one portion is bright in the whole of the dark object, for example, this bright portion becomes the so-called white compression so that the gradation of this portion cannot be expressed.

SUMMARY OF THE INVENTION

In view of the aforesaid aspect, it is an object of the present invention to provide a display device in which an average luminance signal is measured from a luminance signal or three primary color signals or digital three primary

color signals and a predetermined gamma correction, controlled by the average luminance signal, is carried out so that, while a maximum output of a video signal is held at a constant level, an intermediate luminance level is increased in a scene in which an object luminance level is low to thereby make an image of a dark scene become easy to see.

According to the present invention, there is provided a display device which is comprised of a separating circuit for separating a video signal inputted in the form of an analog signal to provide a luminance signal and color-difference signals or video signal input terminals to which the luminance signal and the color-difference signals are supplied separately, a converting circuit for converting the luminance signal and the color-difference signals into three primary color signals or primary signal input terminals to which the three primary color signals are supplied independently, and an A/D-converting means for converting the three primary color signals in the form of analog to digital signals or digital input terminals to which the thus digitally-converted three primary color signals are supplied independently.

To attain the above-mentioned object, the display device according to the present invention comprises a means for measuring an average luminance level from the luminance signal or the three primary color signals or the digital three primary color signals, and a correction means having a predetermined gamma correction curve controlled by an output signal from the measuring means.

Since the gamma correction curve of the correction means is feedforward-controlled or feedback-controlled in response to the average luminance level from the measuring means, in a scene in which an object luminance level is low, an intermediate luminance level is increased to make an image of a dark scene become easy to see. In that case, since the maximum output of the video signal is held at the constant level, even in a scene in which only one portion is bright in the whole dark object, a gradation of the bright portion may be expressed satisfactorily.

According to a first aspect of the present invention, there is provided a display device including a separating circuit for separating a video signal inputted in the form of an analog signal to provide a luminance signal and color-difference signals or video signal input terminals to which the luminance signal and the color-difference signals are supplied separately, a converting circuit for converting the luminance signal and the color-difference signals into three primary color signals or primary color signal input terminals to which the three primary color signals are supplied independently, and an A/D converting means for converting the three primary color signals in the form of analog to digital signals or digital input terminals to which the digitally-converted three primary color signals are supplied independently. This display device comprises a measuring means for measuring an average luminance level of the luminance signal supplied from the separating circuit or video signal input terminal or the three primary color signals supplied from the converting circuit or the primary color signal input terminals or the digitally-converted three primary color signals supplied from the A/D converting means or digital input terminals, and a gamma correction means having a gamma correction curve controlled by an output control signal from the measuring means.

According to a second aspect of the present invention, in the above-mentioned display device, the measuring means includes a comparing means for being supplied with an analog luminance signal from the separating circuit or the video signal input terminals and for comparing the analog

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luminance signal with a predetermined level, an integrating circuit for integrating an output from the comparing circuit, and a control circuit for generating an output control signal based on an integrated value from the integrating circuit.

According to a third aspect of the present invention, in the above-mentioned display device, the measuring means includes an analog luminance signal generating circuit for being supplied with analog three primary color signals from the converting circuit or the primary color signal input terminals and for generating an analog luminance signal by adding the three primary color signals with a predetermined ratio, a comparing circuit for comparing the generated analog luminance signal with a predetermined level, an integrating circuit for integrating an output from the comparing circuit, and a control circuit for generating an output control signal based on an integrated value from the integrating circuit.

According to a fourth aspect of the present invention, in the above-mentioned display device, the measuring means includes a digital luminance signal generating circuit for being supplied with the digitally-converted three primary color signals from the A/D converting means or the digital input terminals and for generating a digital luminance signal by adding the digitally-converted three primary color signals with a predetermined ratio, a comparing circuit for comparing the generated digital luminance signal with a predetermined level, an integrating circuit for integrating an output from the integrating circuit, and a control circuit for generating an output control signal based on an integrated value from the integrating circuit.

According to a fifth aspect of the present invention, in the above mentioned display device, the gamma correction curve of the gamma correction means has a control characteristic such that the gamma correction curve is made approximately a straight line when the level of the output control signal from the measuring means is large and that an intermediate signal level is increased as the level of the output control signal from the measuring means is lowered.

According to a sixth aspect of the present invention, in the above-mentioned display device, the gamma correction means is provided with respect to the analog luminance signal supplied from the separating circuit or the video signal input terminals, the output control signal from the measuring means is generated based on the analog luminance signal from the separating circuit or the video signal input terminals and the gamma correction means is feedforward-controlled by the output control signal from the measuring means.

According to a seventh aspect of the present invention, in the above-mentioned display device, the gamma correction means is provided with respect to the analog luminance signal supplied from the separating circuit or the video signal input terminals, the output control signal from the measuring means is generated based on the analog luminance signal outputted from the gamma correction means and the gamma correction means is feedback-controlled by the output control signal from the measuring means.

According to an eight aspect-of the present invention, in the above-mentioned display device, the gamma correction means is provided with respect to the analog luminance signal supplied from the separating circuit or the video signal input terminals, the output control signal from the measuring means is generated based on the analog three primary color signals outputted from the converting circuit and the gamma correction means is feedback-controlled by the output control signal from the measuring means.

According to a ninth aspect of the present invention, in the above-mentioned display device, the gamma correction means is provided with respect to the analog luminance signal from the separating circuit or the video signal input terminals, the output control signal supplied from the measuring means is generated based on the digitally-converted three primary color signals outputted from an A/D converting means and the gamma correction means is feedback-controlled by the output control signal from the measuring means.

According to a tenth aspect of the present invention, in the above-mentioned display device, the gamma correction means is provided with respect to the analog luminance signal supplied from the separating circuit or the video signal input terminals, and also provided with a color gain control means in order to control levels of two color-difference signals comprising the video signal in response to the measured average luminance level, the output control signal from the measuring means is generated based on the analog luminance signal supplied from the separating circuit or the video signal input terminals, and the gamma correction means and the color gain control means are feedforward-controlled by the output control signal from the measuring means.

According to an eleventh aspect of the present invention, in the above-mentioned display device, the gamma correction means is provided with respect to the analog luminance signal supplied from the separating circuit or the video signal input terminals, also provided with a color gain control means in order to control levels of two color-difference signals comprising the video signal in response to the measured average luminance level, the output control signal from the measuring means is generated based on the analog luminance signal supplied from the gamma correction means, and the gamma correction means and the color gain control means are feedback-controlled by the output control signal from the measuring means.

According to a twelfth aspect of the present invention, in the above-mentioned display device, the gamma correction means is provided with respect to the analog luminance signal supplied from the separating circuit or the video signal input terminals, also provided with a color gain control means in order to control levels of two color-difference signals comprising the video signal in response to the measured average luminance level, the output control signal from the measuring means is generated based on the analog three primary color signals outputted from the converting means and the gamma correction means and the color gain control means are feedback-controlled by the output control signal from the measuring means.

According to a thirteenth aspect of the present invention, in the above-mentioned display device, the gamma correction means is provided with respect to the analog luminance signal supplied from the separating circuit or the video signal input terminals, also provided with a color gain control means in order to control levels of two color-difference signals comprising the video signal in response to the measured average luminance level, the output control signal from the measuring means is generated based on the digitally-converted three primary color signals outputted from the A/D converting means, and the gamma correction means and the color gain control means are feedback-controlled by the output control signal from the measuring means.

According to a fourteenth aspect of the present invention, in the above-mentioned display device, the gamma correc-

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tion means are provided with respect to respective three primary color signals outputted from the converting circuit, the output control signal from the measuring means is generated based on the analog luminance signal supplied from the separating circuit or the video signal input terminals, and the gamma correction means are respectively feedforward-controlled by the output control signal from the measuring means.

According to a fifteenth aspect of the present invention, in the above-mentioned display device, the gamma correction means are provided with respect to the respective three primary color signals outputted from the converting circuit or the primary color signal input terminals, the output control signal from the measuring means is generated based on the analog three primary color signals supplied from the converting circuit or the primary color signal input terminals, and the gamma correction means are respectively feedforward-controlled by the output control signal from the measuring means.

According to a sixteenth aspect of the present invention, in the above-mentioned display device, the gamma correction means are provided with respect to the respective three primary color signals supplied from the converting circuit or the primary color signal input terminals, the output control signal from the measuring means is generated based on the analog three primary color signals outputted from the gamma correction means, and the gamma correction means are respectively feedback-controlled by the output control signal from the measuring means.

According to a seventeenth aspect of the present invention, in the above-mentioned display device, the gamma correction means are provided with respect to the respective three primary color signals supplied from the converting circuit or the primary color signal input terminals, the output control signal from the measuring means is generated based on the digitally-converted three primary color signals outputted from the A/D converting means, and the gamma correction means are respectively feedback-controlled by the output control signal from the measuring means.

According to an eighteenth aspect of the present invention, in the above-mentioned display device, the gamma correction means are provided with respect to the respective digitally-converted three primary color signals outputted from the A/D converting means, the output control signal from the measuring means is generated based on the analog luminance signal supplied from the separating circuit or the video signal input terminals, and the gamma correction means are respectively feedforward-controlled by the output control signal from the measuring means.

According to a nineteenth aspect of the present invention, in the above-mentioned display device, the gamma correction means are provided with respect to the respective digitally-converted three primary color signals outputted from the A/D converting means, the output control signal from the measuring means is generated based on the analog three primary color signals supplied from the converting circuit or the primary color input terminals, and the gamma correction means are respectively feedforward-controlled by the output control signal from the measuring means.

According to a twentieth aspect of the present invention, in the above-mentioned display device, the gamma correction means are provided with respect to the respective digitally-converted three primary color signals supplied from the A/D converting means or the digital input terminals, the output control signal from the measuring means is generated based on the digitally-converted three primary color signals supplied from the A/D converting means or the digital input terminals, and the gamma correction means are respectively feedforward-controlled by the output control signal from the measuring means.

In accordance with a twenty-first aspect of the present invention, in the above-mentioned display device, the gamma correction means are provided with respect to the respective three primary color signals supplied from the A/D converting means or the digital input terminals, the output control signal from the measuring means is generated based on the digital three primary color signals outputted from the gamma correction means, and the gamma correction means are respectively feedback-controlled by the output control signal from the measuring means.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram showing a display device according to a first embodiment of the present invention;

FIG. **2** is a characteristic graph used to explain an operation of the display device according to the present invention shown in FIG. **1**;

FIG. **3** is a circuit diagram showing a main portion of the display device according to the present invention shown in FIG. **1**;

FIG. **4** is a characteristic graph used to explain an operation of the circuit diagram shown in FIG. **3**;

FIG. **5** is a block diagram showing a display device according to a second embodiment of the present invention;

FIG. **6** is a block diagram showing a display device according to a third embodiment of the present invention;

FIG. **7** is a block diagram showing a display device according to a fourth embodiment of the present invention;

FIG. **8** is a block diagram showing a display device according to a fifth embodiment of the present invention;

FIG. **9** is a block diagram showing a display device according to a sixth embodiment of the present invention;

FIG. **10** is a block diagram showing a display device according to a seventh embodiment of the present invention;

FIG. **11** is a block diagram showing a display device according to an eight embodiment of the present invention;

FIG. **12** is a block diagram showing a display device according to a ninth embodiment of the present invention;

FIG. **13** is a block diagram showing a display device according to a tenth embodiment of the present invention;

FIG. **14** is a block diagram showing a display device according to an eleventh embodiment of the present invention;

FIG. **15** is a block diagram showing a display device according to a twelfth embodiment of the present invention;

FIG. **16** is a block diagram showing a display device according to a thirteenth embodiment of the present invention;

FIG. **17** is a block diagram showing a display device according to a fourteenth embodiment of the present invention;

FIG. **18** is a block diagram showing a display device according to a fifteenth embodiment of the present invention; and

FIG. **19** is a block diagram showing a display device according to a sixteenth embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will hereinafter be described with reference to the accompanying drawings.

FIG. 1 of the accompanying drawings is a block diagram showing a display device according to a first embodiment of the present invention.

Referring to FIG. 1, the display device includes an input terminal 1 to which there is supplied a composite video signal (video signal), for example. The composite video signal from this input terminal 1 is supplied to a separating circuit 2 which separates the composite video signal, for example, to provide a luminance signal (Y) and two color-difference signals (R–Y), (B–Y). The luminance signal (Y) and the two color-difference signals (R–Y) and (B–Y) separated by the separating circuit 2 are supplied to change-over switches 3Y, 3R, 3B, in which they are switched from signals supplied from an input terminal (component input terminal) 4 to which a luminance signal (Y) and two color-difference signals (R–Y), (B–Y), for example, are supplied, respectively.

The luminance signal (Y) from this change-over switch 3Y is supplied to a gamma correction device (dynamic gamma circuit) 5 having a gamma correction curve that is controlled by an output control signal Vc from a control circuit 11 which will be described later on. The dynamic control circuit 5 is controlled by the output control signal Vc from the control circuit 11, which will be described later on, in such a manner that a gamma correction curve between an input and output thereof, for example, is presented as shown in FIG. 2, for example. Specifically, the dynamic control circuit 5 is controlled in response to the level of the output control signal Vc in such a manner that the intermediate signal level of the input and output correction curve is increased from approximately a straight line as shown by an arrow in FIG. 2, for example.

Further, the corrected luminance signal (Y) from the dynamic gamma circuit 5 and the two color-difference signals (R–Y), (B–Y) from the above-mentioned change-over switches 3R, 3B are respectively supplied to a converting circuit 6, in which they are converted into three primary color signals of red (R), green (G), blue (B), for example. The three primary color signals (R/G/B) thus converted by this converting circuit 6 are respectively supplied to A/D (analog-to-digital) converting circuits 7R, 7G, 7B, and resultant digital three primary color signals (R/G/B) are supplied from the A/D converting circuits 7R, 7G, 7B to a display device 8 such as a plasma display and a liquid-crystal display.

On the other hand, the luminance signal (Y) from the change-over switch 3Y is supplied to a comparing circuit 9, which compares a supplied signal with an arbitrary reference level, and thereby converted into a square-wave signal which goes to "0" when it is higher than the reference level and which goes to "1" when it is lower than the reference level. This square-wave signal is integrated by an integrating circuit 10 in which generated is a signal indicative of an average luminance signal of the above-mentioned luminance signal (Y). Incidentally, this integrating circuit 10 is of a 5V-system circuit, for example. Therefore, the signal thus generated is supplied to the control circuit 11 which effects the voltage-conversion from 5V to 12V, for example, in order to establish an electrical interface between the integrating circuit 10 and the dynamic gamma circuit 5. Then, the output control signal Vc thus voltage-converted by this control circuit 11 is supplied to the dynamic gamma circuit 5.

In this manner, in this display device, the average luminance level of the luminance signal (Y) supplied from the separating circuit 2, for example, or the component input terminal 4 through the change-over switch 3Y is measured by the measuring means comprising the comparing circuit 9 to the control circuit 11. Further, the output control signal Vc corresponding to the average luminance level measured by this measuring means is supplied from the control circuit 11 to the dynamic gamma circuit 5. Then, the gamma correction curve of the above-mentioned dynamic gamma circuit 5 is feedforward-controlled in such a fashion that the gamma correction curve between input and output is presented as approximately a straight line when the average luminance level, for example, is large and that the intermediate signal level, for example, of the gamma correction between input and output is increased when the average luminance level is low.

Accordingly, since this display device includes the measuring means for measuring the average luminance level of the video signal to be displayed and the gamma correction means controlled by the output control signal from this measuring means, the gamma correction curve is controlled in response to the average luminance level of the displayed video signal, whereby the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily.

In the conventional display device, it is frequently observed that an image becomes difficult to see in the scene in which a luminance level of an object, for example, is low. To solve this problem, when a contrast in the whole of the object is increased, even in the scene in which one portion is bright in the whole of the dark object, for example, this bright portion becomes a so-called white compression. There then arises a problem that the gradation of this portion cannot b expressed. According to the present invention, these problems may be solved with ease.

FIG. 3 shows an example of a specific circuit arrangement that can realize the above-mentioned dynamic gamma circuit 5. As shown in FIG. 3, the luminance signal (Y) from the above-mentioned change-over switch 3Y, for example, is supplied to an input terminal 30. The output control signal (voltage) Vc is supplied from the above-mentioned control circuit 11 to a control terminal 31. Then, the luminance signal (Y) supplied to the input terminal 30 is supplied to a gain control circuit 32 which is controlled by the above-mentioned output control signal Vc, for example, and a signal from this gain control circuit 32 is supplied to a pedestal clamp circuit 33.

An output terminal of this pedestal clamp circuit 33 is connected to the base of an npn-type transistor 34. The collector of this transistor 34 is connected to a power-supply line 35 of a power supply Vcc. The emitter of this transistor 34 is connected to the ground through a resistor 36, and an output terminal 38 is led out from the emitter of this transistor 34 through a resistor 37.

On the other hand, the control terminal 31 to which the above-mentioned output control signal (voltage) Vc is supplied is connected to the base of an npn-type transistor 39. Then, the emitter of this transistor 39 is connected to the ground through a resistor 40. Also, the collector of this transistor 39 is connected to the power-supply line 35 of the power supply Vcc through a resistor 41. The collector of this transistor 39 is connected to the base of an npn-type transistor 42.

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Further, the collector of this transistor 42 is connected to the power-supply line 35 of the power-supply Vcc. Also, the emitter of this transistor 42 is connected through a resistor 43 to an integrating circuit comprising a resistor 44 and a capacitor 45. Further, a junction (a) between the resistor 43 and the integrating circuit is connected to the base of a pnp-type transistor 46. Then, the collector of this transistor 46 is connected to the ground, and the emitter of this transistor 46 is connected through a resistor 47 to a junction between the resistor 37 and the output terminal 38.

In this circuit shown in FIG. 3, the above-mentioned gain control circuit 32 has such an arrangement that the gain of the input and output characteristic increases as the output control signal (voltage) Vc increases, for example. Then, the luminance signal (Y) supplied to the input terminal 30 is supplied through this gain control circuit 32 to the pedestal clamp circuit 33. The video signal whose pedestal is clamped by this pedestal clamp circuit 33 is supplied through an emitter-follower of the transistor 34 to a "polygonal line circuit" comprising the resistors 37, 47 and the transistor 46.

In this "polygonal line circuit", if the signal level at the emitter (junction b) of the transistor 34 is lower than [voltage at the above-mentioned junction a+base-emitter voltage Vbe of the transistor 46], then although the transistor 46 is turned off, the signal level at the junction b is developed at the output terminal 38 as it is. On the other hand, if the signal level at the junction b becomes higher than [voltage at the above-mentioned junction a+base-emitter voltage Vbe of the transistor 46], then the transistor 46 is turned on so that the signal level at the junction b is divided by the resistors 37, 47 and then developed at the output terminal 38.

Specifically, in this "polygonal line circuit", when the signal level at the junction b is lower than [voltage at the above-mentioned junction a+base-emitter voltage Vbe of the transistor 46], the gain thereof becomes "1". When this signal level becomes higher than the above-mentioned voltage, the gain thereof becomes smaller than "1" that is determined by the resistance ratio between the resistors 37, 47 with the result that the input and output characteristic is bent at the point of the [voltage at the above-mentioned junction a+base-emitter voltage Vbe of the transistor 46].

An operation of the circuit shown in FIG. 3 will be described below. When the correction is not carried out since the output control signal Vc is not supplied to the control terminal 31, the signal supplied to the input terminal 30 is outputted to the output terminal 38 as it is. On the other hand, when the voltage of the output control signal Vc supplied to the control terminal 31 increases, the circuit comprised of the transistors 39, 42 and the resistors 40, 41, 43, 44 lowers the voltage at the junction a to cause the input and output characteristic to be bent at the portion in which the signal level is high.

Further, when the voltage of the output control signal Vc is increased, then the gain of the portion in which the signal level is low is increased by the gain control circuit 32. At the same time, the signal level obtained at the portion in which the input and output characteristic is bent is lowered so that the gain of the portion above that point is decreased. Thus, there is generated an input and output characteristic shown in FIG. 4, for example.

That is, in the circuit shown in FIG. 3, if the voltage of the output control signal Vc is increased progressively, then the gamma correction curve between input and output is controlled in such a manner that its intermediate signal level is increased from approximately a straight line as shown by the arrow in FIG. 4. Also, at that time, by the cooperation of the gain control circuit 32 and the polygonal line circuit, it is possible to hold the maximum value Vomax of the output level, for example, at the constant level.

Accordingly, in this circuit, while the maximum value Vomax of the output level is held at the constant level, the polygonal points may be moved in unison with the gain and the intermediate luminance level may be changed dynamically, thereby making it possible to effect the correction without damaging the gradation of the white peak. Moreover, this circuit does not need any special integrated circuit and a complex circuit or the like so that this circuit may be realized by a simple arrangement at a low cost.

FIG. 5 is a block diagram showing a display device according to a second embodiment of the present invention.

Referring to FIG. 5, the display device includes an input terminal 1 to which there is supplied a composite video signal (video signal), for example. The composite video signal from this input terminal 1 is supplied to a separating circuit 2 which separates the composite video signal, for example, to provide a luminance signal (Y) and two color-difference signals (R−Y), (B−Y). The luminance signal (Y) and the two color-difference signals (R−Y) and (B−Y) separated by the separating circuit 2 are supplied to change-over switches 3Y, 3R, 3B, in which they are switched from signals supplied from an input terminal (component input terminal) 4 to which a luminance signal (Y) and two color-difference signals (R−Y), (B−Y), for example, are supplied, respectively.

The luminance signal (Y) from this change-over switch 3Y is supplied to a gamma correction device (dynamic gamma circuit) 5 having a gamma correction curve that is controlled by an output control signal Vc from a control circuit 11 which will be described later on. The dynamic control circuit 5 is controlled by the output control signal Vc from the control circuit 11, which will be described later on, in such a manner that an input and output gamma correction curve, for example, is presented as shown in FIG. 2, for example. Specifically, the dynamic control circuit 5 is controlled by the output control signal Vc in such a manner that the intermediate signal level of the gamma correction curve between input and output is increased from approximately a straight line as shown by an arrow in FIG. 2, for example.

Further, the corrected luminance signal (Y) from the dynamic gamma circuit 5 and the two color-difference signals (R−Y), (B−Y) from the above-mentioned change-over switches 3R, 3B are all supplied to a converting circuit 6, in which they are converted into three primary color signals of red (R), green (G), blue (B), for example. The three primary color signals (R/G/B) thus converted by this converting circuit 6 are respectively supplied to A/D (analog-to-digital) converting circuits 7R, 7G, 7B, and resultant digital three primary color signals (R/G/B) are supplied from the A/D converting circuits 7R, 7G, 7B to a display device 8 such as a plasma display or a liquid-crystal display.

Further, the luminance signal (Y) from the dynamic gamma circuit 5 is supplied to a comparing circuit 9 to be compared with an arbitrary reference level and thereby converted into a square-wave signal which goes to "0" when it is higher than the reference level and which goes to "1" when it is lower than the reference level. This square-wave signal is integrated by an integrating circuit 10 and thereby generated as the signal indicative of the average luminance signal of the above-mentioned luminance signal (Y). Incidentally, this integrating circuit 10 is of a 5V-system

circuit, for example. Therefore, the signal thus generated is supplied to a control circuit 11 which effects the voltage-conversion from 5V to 12V, for example, in order to establish an electrical interface between the integrating circuit 10 and the dynamic gamma circuit 5. Then, the output control signal Vc thus voltage-converted by this control circuit 11 is supplied to the dynamic gamma circuit 5.

In this manner, in this display device, the average luminance level of the luminance signal (Y) outputted from the dynamic gamma circuit 5 is measured by the measuring means comprising the comparing circuit 9 to the control circuit 11. Further, the output control signal Vc corresponding to the average luminance level measured by this measuring means is supplied from the control circuit 11 to the dynamic gamma circuit 5. Then, the gamma correction curve of the above-mentioned dynamic gamma circuit 5 is feedback-controlled in such a fashion that the gamma correction between input and output becomes approximately a straight line when the average luminance level is large and that the intermediate signal level, for example, is increased when the average luminance level becomes small.

Accordingly, since this display device includes the measuring means for measuring the average luminance level of the video signal to be displayed and the gamma correction means controlled by the output control signal from this measuring means, the gamma correction curve is controlled in response to the average luminance level of the video signal to be displayed, whereby the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily.

FIG. 6 is a block diagram showing a display device according to a third embodiment of the present invention.

As shown in FIG. 6, the display device includes an input terminal 1 to which a composite video signal (video signal), for example, is supplied. The composite video signal from this input terminal 1 is supplied to a separating circuit 2 which separates the composite video signal, for example, to provide a luminance signal (Y) and two color-difference signals (R−Y), (B−Y). Further, the luminance signal (Y) and the two color-difference signals (R−Y), (B−Y) separated by this separating circuit 2 are respectively supplied to change-over switches 3Y, 3R, 3B, in which they are respectively switched from the signals from an input terminal (component input terminal) 4 to which the luminance signal (Y) and the two color-difference signals (R−Y), (B−Y) are supplied respectively.

The luminance signal (Y) from this change-over switch 3Y is supplied to a gamma correction means (dynamic gamma circuit) 5 having a gamma correction curve controlled by an output control circuit 11 which will be described later on. In the dynamic gamma circuit 5, a gamma correction characteristic curve between its input and output, for example, is controlled by the output control signal Vc from the control circuit 11, which will be described later on, in such a way as shown in FIG. 2, for example. That is, the correction curve between the input and output thereof is controlled as shown by the arrow in FIG. 2 in response to the magnitude of the output control signal Vc in such a manner that the intermediate signal level is increased from approximately a straight line.

Further, the corrected luminance signal (Y) from the dynamic gamma circuit 5 and the two color-difference signals (R−Y), (B−Y) from the above-mentioned change-over switches 3R, 3B are all supplied to a converting circuit 6, in which they are converted into three primary color signals of red (R), green (G), blue (B). Then, the three primary color signals (R/G/B) thus converted by this converting circuit 6 are respectively supplied to A/D converting circuits 7R, 7G, 7B from which the three primary color signals (R/G/B) thus digitally-converted are supplied to a display means 8 such as a plasma display or a liquid-crystal display.

Also, the three primary color signals (R/G/B) thus converted by the above-mentioned converting circuit 6 are supplied to an analog luminance signal generating circuit 12A. This luminance signal generating circuit 12A generates a luminance signal (Y) by adding the three primary color signals (R/G/B) with a predetermined ratio, e.g. at a ratio of $Y=0.30R+0.59G+0.11B$ in the case of the NTSC system. The thus generated luminance signal (Y) is supplied to a comparing circuit 9, which compares a supplied luminance signal with an arbitrary reference level, and thereby converted into a square-wave signal which goes to "0" when it is higher than the reference level and which goes to "1" when it is lower than the reference level.

Further, an integrating circuit 10 integrates this square-wave signal to generate a signal indicative of the average luminance level of the above-mentioned luminance signal (Y). Incidentally, this integrating circuit 10 is of a 5V-system circuit, for example. Accordingly, the above-mentioned generated signal is supplied to the control circuit 11 which effects the voltage-conversion from 5V to 12V, for example, in order to establish an electrical interface between the above-mentioned dynamic gamma circuit 5 and the integrating circuit 10. Then, the output control signal Vc thus voltage-converted by this control circuit 11 is supplied to the dynamic gamma circuit 5.

As described above, according to this display device, the luminance signal Y is generated from the three primary color signals (R/G/B) converted by the converting circuit 6, and the average luminance level of this luminance signal (Y) is measured by the measuring means comprising the comparing circuit 9 to the control circuit 11. Further, the output control signal Vc, which corresponds to the average luminance level measured by this measuring means, from the control circuit 11 is supplied to the dynamic gamma circuit 5. Then, the gamma correction curve of the above-mentioned dynamic gamma circuit 5 is feedback-controlled in such a manner that the gamma correction between input and output becomes approximately a straight line when the average luminance level, for example, is large and that the intermediate signal level, for example, is increased when the average luminance level becomes small.

Accordingly, since this display device includes the measuring means for measuring the average luminance level of the video signal to be displayed and the gamma correction means controlled by the output control signal from this measuring means, the gamma correction curve is controlled in response to the average luminance level of the video signal to be displayed, whereby the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily.

FIG. 7 is a block diagram showing a display device according to a fourth embodiment of the present invention.

As shown in FIG. 7, the display device includes an input terminal 1 to which a composite video signal (video signal), for example, is supplied. The composite video signal from this input terminal 1 is supplied to a separating circuit 2 which separates the composite video signal, for example, to provide a luminance signal (Y) and two color-difference signals (R−Y), (B−Y). Further, the luminance signal (Y) and the two color-difference signals (R−Y), (B−Y) separated by this separating circuit 2 are supplied to change-over switches 3Y, 3R, 3B, in which they are respectively switched from the signals from an input terminal (component input terminal) 4 to which the luminance signal (Y) and the two color-difference signals (R−Y), (B−Y) are supplied respectively.

The luminance signal (Y) from this change-over switch 3Y is supplied to a gamma correction means (dynamic gamma circuit) 5 having a gamma correction curve controlled by the output control signal Vc from an output control circuit 11 which will be described later on. In the dynamic gamma circuit 5, a gamma correction characteristic curve between its input and output, for example, is controlled by the output control signal Vc from the control circuit 11, which will be described later on, in such a way as shown in FIG. 2, for example. That is, the gamma correction curve between input and output is controlled as shown by the arrow in FIG. 2 in response to the magnitude of the output control signal Vc in such a manner that the intermediate signal level is increased from approximately a straight line.

Further, the corrected luminance signal (Y) from the dynamic gamma circuit 5 and the two color-difference signals (R−Y), (B−Y) from the above-mentioned change-over switches 3R, 3B are all supplied to a converting circuit 6, in which they are converted into three primary color signals of red (R), green (G), blue (B), for example. Then, the three primary color signals (R/G/B) thus converted by this converting circuit 6 are respectively supplied to A/D converting circuits 7R, 7G, 7B from which the three primary color signals (R/G/B) thus digitally-converted are supplied to a display means 8 such as a plasma display or a liquid-crystal display.

Also, the three primary color signals (R/G/B) thus digitally converted by the above-mentioned A/D converting circuits 7R, 7G, 7B are supplied to a digital luminance signal generating circuit 12D. The three primary color signals (R/G/B) outputted from the A/D converting circuits 7R, 7G, 7B are digital signals in which a sampling frequency, for example, is 30 MHz and the quantization bit number is 8 bits (quantization value ranges from 0 to 255). This luminance signal generating circuit 12D generates a luminance signal (Y) by adding the three primary color signals (R/G/B) with a predetermined ratio, e.g. at a ratio of $Y=0.30R+0.59G+0.11B$ in the case of the NTSC system.

The thus generated luminance signal (Y: digital value) is supplied to a comparing circuit 9, which compares a supplied luminance signal with an arbitrary reference level, e.g. quantization value 100, and thereby converted into a square-wave signal which goes to "0" when it is higher than the reference level and which goes to "1" when it is lower than the reference level. An integrating circuit 10 integrates this square-wave signal to generate a signal (analog value) indicative of the average luminance level of the above-mentioned luminance signal (Y). Incidentally, this integrating circuit 10 is of the 5V-system circuit, for example. Accordingly, the above-mentioned generated signal is supplied to the control circuit 11 which effects the voltage-conversion from 5V to 12V, for example, in order to establish the electrical interface between the above-mentioned dynamic gamma circuit 5 and the integrating circuit 10. Then, the output control signal Vc thus voltage-converted by this control circuit 11 is supplied to the dynamic gamma circuit 5.

As described above, according to this display device, the luminance signal (Y: digital value) is generated from the three primary color signals (R/G/B) thus converted by the A/D converting circuits 7R, 7G, 7B, and the average luminance level (analog value) of the luminance signal (Y) is measured by the measuring means comprising the comparing circuit 9 to the control circuit 11. Further, the output control signal Vc, which corresponds to the average luminance level measured by this measuring means, from the control circuit 11 is supplied to the dynamic gamma circuit 5. Then, the gamma correction curve of the above-mentioned dynamic gamma circuit 5 is feedback-controlled in such a manner that the gamma correction between input and output becomes approximately a straight line when the average luminance level, for example, is large and that the intermediate signal level, for example, is increased when the average luminance level becomes small.

Accordingly, since this display device includes the measuring means for measuring the average luminance level of the video signal to be displayed and the gamma correction means controlled by the output control signal from this measuring means, the gamma correction curve is controlled in response to the average luminance level of the video signal to be displayed, whereby the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily.

In the above-mentioned apparatus, by the way, since the signal levels are related to not the brightness but a color saturation degree with respect to the two color-difference signals (R−Y) and (B−Y), the two color-difference signals (R−Y) and (B−Y) cannot be processed by the gamma correction similarly to the luminance signal (Y). However, it is considered that when only the luminance signal (Y) is increased by the correction, for example, the color saturation degree is lowered relatively to thereby cause colors to become plain. Therefore, with respect to the two color-difference signals (R−Y) and (B−Y), by the provision of a color gain control circuit in which the gain of input and output characteristics is increased as the control signal (voltage) Vc, for example, is increased, it is possible to solve the problem in which the color saturation degree is lowered relatively.

FIG. 8 is a block diagram showing a display device including such a color gain control circuit according to a fifth embodiment of the present invention.

As shown in FIG. 8, the display device includes an input terminal 1 to which a composite video signal (video signal), for example, is supplied. The composite video signal from this input terminal 1 is supplied to a separating circuit 2 which separates the composite video signal, for example, to provide a luminance signal (Y) and two color-difference signals (R−Y), (B−Y). Further, the luminance signal (Y) and the two color-difference signals (R−Y), (B−Y) separated by this separating circuit 2 are respectively supplied to change-over switches 3Y, 3R, 3B, in which they are respectively switched from the signals from an input terminal (component input terminal) 4 to which the luminance signal (Y) and the two color-difference signals (R−Y), (B−Y) are supplied respectively

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The luminance signal (Y) from this change-over switch 3Y is supplied to a gamma correction means (dynamic gamma circuit) 5 having a gamma correction curve controlled by an output control signal Vc from an output control circuit 11 which will be described later on. In the dynamic gamma circuit 5, a gamma correction characteristic curve between its input and output, for example, is controlled by the output control signal Vc from the control circuit 11, which will be described later on, in such a way as shown in FIG. 2, for example. That is, the gamma correction curve between input and output is controlled as shown by the arrow in FIG. 2 in response to the magnitude of the output control signal Vc in such a manner that the intermediate signal level is increased from approximately a straight line.

Also, the two color-difference signals (R−Y) and (B−Y) from the change-over switches 3R, 3B are supplied to a color gain control circuit 13 which is controlled by the output control signal Vc from the control circuit 11 which will be described later on. Here, the color gain control circuit 13 is arranged such that the gain of input and output characteristics is increased as the control signal (voltage) Vc, for example, is increased.

Further, the corrected luminance signal (Y) from the dynamic gamma circuit 5 and the two color-difference signals (R−Y), (B−Y) gain-controlled from the color gain control circuit 13 are all supplied to a converting circuit 6, in which they are converted into three primary color signals of red (R), green (G), blue (B), for example. Then, the three primary color signals (R/G/B) thus converted by this converting circuit 6 are respectively supplied to A/D converting circuits 7R, 7G, 7B from which the three primary color signals (R/G/B) thus digitally-converted are supplied to a display means 8 such as a plasma display or a liquid-crystal display.

On the other hand, the luminance signal (Y) from the change-over switch 3Y is supplied to a comparing circuit 9 to be compared with an arbitrary reference level and thereby converted into a square-wave signal which goes to "0" when it is higher than the reference level and which goes to "1" when it is lower than the reference level. This square-wave signal is integrated by an integrating circuit 10 and thereby generated as the signal indicative of the average luminance level of the above-mentioned luminance signal (Y). Incidentally, this integrating circuit 10 is of a 5V-system circuit, for example. Therefore, the signal thus generated is supplied to the control circuit 11 which effects the voltage-conversion from 5V to 12V, for example, in order to establish an electrical interface between the above-mentioned dynamic gamma circuit 5 and the color gain control circuit 13. Then, the output control signal Vc thus voltage-converted by this control circuit 11 is supplied to the dynamic gamma circuit 5 and the color gain control circuit 13.

As described above, according to this display device, the average luminance level of the luminance signal (Y) supplied from the separating circuit 2, for example, or the component input terminal 4 through the change-over switch 3Y is measured by the measuring means comprising the comparing circuit 9 to the control circuit 11. Further, the output control signal Vc, which corresponds to the average luminance level measured by this measuring means, from the control circuit 11 is supplied to the dynamic gamma circuit 5 and the color gain control circuit 13.

Then, the gamma correction curve of the above-mentioned dynamic gamma circuit 5 is feedforward-controlled in such a manner that the gamma correction between input and output becomes approximately a straight line when the average luminance level, for example, is large and that the intermediate signal level, for example, is increased when the average luminance level becomes small. Also, the color gain control circuit 13 is feedforward-controlled in such a manner that the color gain is increased when the average luminance level, for example, is large and that the color gain is decreased when the average luminance level becomes small.

Accordingly, since this display device includes the measuring means for measuring the average luminance level of the video signal to be displayed, the gamma correction means controlled by the output control signal from this measuring means and the color gain control circuit, the gamma correction curve and the color gain are controlled in response to the average luminance level of the video signal to be displayed, whereby the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily. Also, the color gain may be controlled satisfactorily in response to the change of this luminance level.

Further, FIG. 9 is a block diagram showing a display device including a color gain control circuit according to a sixth embodiment of the present invention.

As shown in FIG. 9, the display device includes an input terminal 1 to which a composite video signal (video signal), for example, is supplied. The composite video signal from this input terminal 1 is supplied to a separating circuit 2 which separates the composite video signal, for example, to provide a luminance signal (Y) and two color-difference signals (R−Y), (B−Y). Further, the luminance signal (Y) and the two color-difference signals (R−Y), (B−Y) separated by this separating circuit 2 are respectively supplied to change-over switches 3Y, 3R, 3B, in which they are respectively switched from the signals from an input terminal (component input terminal) 4 to which the luminance signal (Y) and the two color-difference signals (R−Y), (B−Y) are supplied separately.

The luminance signal (Y) from this change-over switch 3Y is supplied to a gamma correction means (dynamic gamma circuit) 5 having a gamma correction curve controlled by an output control signal Vc from an output control circuit 11 which will be described later on. In the dynamic gamma circuit 5, a gamma correction characteristic curve between its input and output, for example, is controlled by the output control signal Vc from the control circuit 11, which will be described later on, in such a way as shown in FIG. 2, for example. That is, the gamma correction curve between input and output is controlled as shown by the arrow in FIG. 2 in response to the magnitude of the output control signal Vc in such a manner that the intermediate signal level is increased from approximately a straight line.

Also, the two color-difference signals (R−Y) and (B−Y) from the change-over switches 3R, 3B are supplied to a color gain control circuit 13 which is controlled by the output control signal Vc from the control circuit 11 which will be described later on. Here, the color gain control circuit 13 is arranged such that the gain of input and output characteristics is increased as the control signal (voltage) Vc, for example, is increased.

Further, the corrected luminance signal (Y) from the dynamic gamma circuit 5 and the two color-difference

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signals (R−Y), (B−Y) gain-controlled from the color gain control circuit **13** are each supplied to a converting circuit **6**, in which they are converted into three primary color signals of red (R), green (G), blue (B), for example. Then, the three primary color signals (R/G/B) thus converted by this converting circuit **6** are respectively supplied to A/D converting circuits 7R, 7G, 7B from which the three primary color signals (R/G/B) thus digitally-converted are supplied to a display means **8** such as a plasma display or a liquid-crystal display.

Further, the luminance signal (Y) from the dynamic gamma circuit **5** is supplied to a comparing circuit **9** to be compared with an arbitrary reference level and thereby converted into a square-wave signal which goes to "0" when it is higher than the reference level and which goes to "1" when it is lower than the reference level. This square-wave signal is integrated by an integrating circuit **10** and thereby generated as the signal indicative of the average luminance level of the above-mentioned luminance signal (Y). Incidentally, this integrating circuit **10** is of a 5V-system circuit, for example. Therefore, the signal thus generated is supplied to the control circuit **11** which effects the voltage-conversion from 5V to 12V, for example, in order to establish an electrical interface between the above-mentioned dynamic gamma circuit **5** and the color gain control circuit **13**. Then, the output control signal Vc thus voltage-converted by this control circuit **11** is supplied to the dynamic gamma circuit **5** and the color gain control circuit **13** mentioned above.

As described above, according to this display device, the average luminance level of the luminance signal (Y) outputted from the dynamic gamma circuit **5** is measured by the measuring means comprising the comparing circuit **9** to the control circuit **11**. Further, the output control signal Vc, which corresponds to the average luminance level measured by this measuring means, from the control circuit **11** is supplied to the dynamic gamma circuit **5** and the color gain control circuit **13**.

Then, the gamma correction curve of the above-mentioned dynamic gamma circuit **5** is feedback-controlled in such a manner that the gamma correction between input and output becomes approximately a straight line when the average luminance level, for example, is large and that the intermediate signal level, for example, is increased when the average luminance level becomes small. Also, the color gain control circuit **13** is feedback-controlled in such a manner that the color gain is increased when the average luminance level, for example, is large and that the color gain is decreased when the average luminance level becomes small.

Accordingly, since this display device includes the measuring means for measuring the average luminance level of the video signal to be displayed, the gamma correction means controlled by the output control signal from this measuring means and the color gain control circuit, the gamma correction curve and the color gain are controlled in response to the average luminance level of the video signal to be displayed, whereby the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily. Also, the color gain may be controlled satisfactorily in response to the change of this luminance level.

Further, FIG. **10** is a block diagram showing a display device including a color gain control circuit according to a seventh embodiment of the present invention.

As shown in FIG. **10**, the display device includes an input terminal **1** to which a composite video signal (video signal), for example, is supplied. The composite video signal from this input terminal **1** is supplied to a separating circuit **2** which separates the composite video signal, for example, to provide a luminance signal (Y) and two color-difference signals (R−Y), (B−Y). Further, the luminance signal (Y) and the two color-difference signals (R−Y), (B−Y) separated by this separating circuit **2** are respectively supplied to change-over switches **3Y**, **3R**, **3B**, in which they are respectively switched from the signals from an input terminal (component input terminal) **4** to which the luminance signal (Y) and the two color-difference signals (R−Y), (B−Y) are supplied separately.

The luminance signal (Y) from this change-over switch **3Y** is supplied to a gamma correction means (dynamic gamma circuit) **5** having a gamma correction curve controlled by an output control signal Vc from an output control circuit **11** which will be described later on. In the dynamic gamma circuit **5**, a gamma correction characteristic curve between its input and output, for example, is controlled by the output control signal Vc from the control circuit **11**, which will be described later on, in such a way as shown in FIG. **2**, for example. That is, the input and output correction curve is controlled as shown by the arrow in FIG. **2** in response to the magnitude of the output control signal Vc in such a manner that the intermediate signal level is increased from approximately a straight line.

Also, the two color-difference signals (R−Y) and (B−Y) from the change-over switches **3R**, **3B** are supplied to a color gain control circuit **13** which is controlled by the output control signal Vc from the control circuit **11** which will be described later on. Here, the color gain control circuit **13** is arranged such that the gain of input and output characteristics is increased as the control signal (voltage) Vc, for example, is increased.

Further, the corrected luminance signal (Y) from the dynamic gamma circuit **5** and the two color-difference signals (R−Y), (B−Y) gain-controlled from the color gain control circuit **13** are each supplied to a converting circuit **6**, in which they are converted into three primary color signals of red (R), green (G), blue (B), for example. Then, the three primary color signals (R/G/B) thus converted by this converting circuit **6** are respectively supplied to A/D converting circuits **7R**, **7G**, **7B** from which the three primary color signals (R/G/B) thus digitally-converted are supplied to a display means **8** such as a plasma display or a liquid-crystal display.

Also, the three primary color signals (R/G/B) thus converted by the above-mentioned converting circuit **6** are supplied to an analog luminance signal generating circuit **12A**. This luminance signal generating circuit **12A** generates a luminance signal (Y) by adding the three primary color signals (R/G/B) with a predetermined ratio, e.g. at a ratio of Y=0.30R+0.59G+0.11B in the case of the NTSC system. The thus generated luminance signal (Y) is supplied to a comparing circuit **9**, which compares a supplied luminance signal with an arbitrary reference level, and thereby converted into a square-wave signal which goes to "0" when it is higher than the reference level and which goes to "1" when it is lower than the reference level.

Further, an integrating circuit **10** integrates this square-wave signal to generate a signal indicative of the average luminance level of the above-mentioned luminance signal (Y). Incidentally, this integrating circuit **10** is of the 5V-system circuit, for example. Accordingly, the above-

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mentioned generated signal is supplied to the control circuit 11 which effects the voltage-conversion from 5V to 12V, for example, in order to establish the electrical interface between the above-mentioned dynamic gamma circuit 5 and the color gain control circuit 13. Then, the output control signal Vc thus voltage-converted by this control circuit 11 is supplied to the dynamic gamma circuit 5 and the color gain control circuit 13.

As described above, according to this display device, the luminance signal (Y) is generated from the three primary color signals (R/G/B) thus converted by the converting circuit 6. The average luminance level of the luminance signal (Y) is measured by the measuring means comprising the comparing circuit 9 to the control circuit 11. Further, the output control signal Vc, which corresponds to the average luminance level measured by this measuring means, from the control circuit 11 is supplied to the dynamic gamma circuit 5 and the color gain control circuit 13.

Then, the gamma correction curve of the above-mentioned dynamic gamma circuit 5 is feedback-controlled in such a manner that the gamma correction between input and output becomes approximately a straight line when the average luminance level, for example, is large and that the intermediate signal level, for example, is increased when the average luminance level becomes small. Also, the color gain control circuit 13 is feedback-controlled in such a manner that the color gain is increased when the average luminance level, for example, is large and that the color gain is decreased when the average luminance level becomes small.

Accordingly, since this display device includes the measuring means for measuring the average luminance level of the video signal to be displayed, the gamma correction means controlled by the output control signal from this measuring means and the color gain control circuit, the gamma correction curve and the color gain are controlled in response to the average luminance level of the video signal to be displayed, whereby the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily. Also, the color gain may be controlled satisfactorily in response to the change of this luminance level.

Further, FIG. 11 is a block diagram showing a display device including a color gain control circuit according to an eight embodiment of the present invention.

As shown in FIG. 11, the display device includes an input terminal 1 to which a composite video signal (video signal), for example, is supplied. The composite video signal from this input terminal 1 is supplied to a separating circuit 2 which separates the composite video signal, for example, to provide a luminance signal (Y) and two color-difference signals (R−Y), (B−Y). Further, the luminance signal (Y) and the two color-difference signals (R−Y), (B−Y) separated by this separating circuit 2 are respectively supplied to change-over switches 3Y, 3R, 3B, in which they are respectively switched from the signals from an input terminal (component input terminal) 4 to which the luminance signal (Y) and the two color-difference signals (R−Y), (B−Y) are supplied separately.

The luminance signal (Y) from this change-over switch 3Y is supplied to a gamma correction means (dynamic gamma circuit) 5 having a gamma correction curve controlled by an output control signal Vc from an output control circuit 11 which will be described later on. In the dynamic gamma circuit 5, a gamma correction characteristic curve between its input and output, for example, is controlled by the output control signal Vc from the control circuit 11, which will be described later on, in such a way as shown in FIG. 2, for example. That is, the gamma correction curve between input and output is controlled as shown by the arrow in FIG. 2 in response to the magnitude of the output control signal Vc in such a manner that the intermediate signal level is increased from approximately a straight line.

Also, the two color-difference signals (R−Y) and (B−Y) from the change-over switches 3R, 3B are supplied to a color gain control circuit 13 which is controlled by the output control signal Vc from the control circuit 11 which will be described later on. Here, the color gain control circuit 13 is arranged such that the gain of input and output characteristics is increased as the control signal (voltage) Vc, for example, is increased.

Further, the corrected luminance signal (Y) from the dynamic gamma circuit 5 and the two color-difference signals (R−Y), (B−Y) with the controlled gains from the color gain control circuit 13 are each supplied to a converting circuit 6, in which they are converted into three primary color signals of red (R), green (G), blue (B), for example. Then, the three primary color signals (R/G/B) thus converted by this converting circuit 6 are respectively supplied to A/D converting circuits 7R, 7G, 7B from which the three primary color signals (R/G/B) thus digitally-converted are supplied to a display means 8 such as a plasma display or a liquid-crystal display.

Also, the three primary color signals (R/G/B) thus digitally converted by the above-mentioned A/D converting circuits 7R, 7G, 7B are supplied to a digital luminance signal generating circuit 12D. The three primary color signals (R/G/B) outputted from the A/D converting circuits 7R, 7G, 7B are digital signals in which a sampling frequency, for example, is 30 MHz and the quantization bit number is 8 bits (quantization value ranges from 0 to 255). This luminance signal generating circuit 12D generates a luminance signal (Y: digital value) by adding the three primary color signals (R/G/B) with a predetermined ratio, e.g. at a ratio of $Y=0.30R+0.59G+0.11B$ in the case of the NTSC system.

The thus generated luminance signal (Y: digital value) is supplied to a comparing circuit 9, which compares a supplied luminance signal with an arbitrary reference level, e.g. quantization value 100, and thereby converted into a square-wave signal which goes to "0" when it is higher than the reference level and which goes to "1" when it is lower than the reference level. An integrating circuit 10 integrates this square-wave signal to generate a signal (analog value) indicative of the average luminance level of the above-mentioned luminance signal (Y). Incidentally, this integrating circuit 10 is of the 5V-system circuit, for example. Accordingly, the above-mentioned generated signal is supplied to the control circuit 11 which effects the voltage-conversion from 5V to 12V, for example, in order to establish the electrical interface between the above-mentioned dynamic gamma circuit 5 and the color gain control circuit 13. Then, the output control signal Vc thus voltage-controlled by this control circuit 11 is supplied to the dynamic gamma circuit 5 and the color gain control circuit 13.

As described above, according to this display device, the luminance signal (Y: digital value) is generated from the three primary color signals (R/G/B) thus converted by the

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A/D converting circuits 7R, 7G, 7B, and the average luminance level (analog value) of this luminance signal (Y) is measured by the measuring means comprising the comparing circuit 9 to the control circuit 11. Further, the output control signal Vc, which corresponds to the average luminance level measured by this measuring means, from the control circuit 11 is supplied to the dynamic gamma circuit 5 and the color gain control circuit 13.

Then, the gamma correction curve of the above-mentioned dynamic gamma circuit 5 is feedback-controlled in such a manner that the gamma correction between input and output becomes approximately a straight line when the average luminance level, for example, is large and that the intermediate signal level, for example, is increased when the average luminance level becomes small. Also, the color gain control circuit 13 is feedback-controlled in such a manner that the color gain is increased when the average luminance level, for example, is large and that the color gain is decreased when the average luminance level becomes small.

Accordingly, since this display device includes the measuring means for measuring the average luminance level of the video signal to be displayed, the gamma correction means controlled by the output control signal from this measuring means and the color gain control circuit, the gamma correction curve and the color gain are controlled in response to the average luminance level of the video signal to be displayed, whereby the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily. Also, the color gain may be controlled satisfactorily in response to the change of the luminance level.

In the above-mentioned apparatus, when a more accurate correction is required, it is considered that, for example, the three primary color signals of red (R), green (G), blue (B) may be corrected. In this case, the three primary color signals of red (R), green (G), blue (B), for example, may be gamma-corrected similarly to the above-mentioned luminance signal (Y).

Specifically, FIG. 12 is a block diagram showing a display device in which each of the three primary color signals of red (R), green (G), blue (B), for example, is gamma-corrected according to a ninth embodiment of the present invention.

As shown in FIG. 12, the display device includes an input terminal 1 to which there is supplied a composite video signal (video signal), for example. The composite video signal from this input terminal 1 is supplied to a separating circuit 2 which separates the composite video signal, for example, to provide a luminance signal (Y) and two color difference signals (R−Y), (B−Y). The luminance signal (Y) and the two color-difference signals (R−Y) and (B−Y) separated by the separating circuit 2 are respectively supplied to change-over switches 3Y, 3R, 3B, in which they are switched from signals supplied from an input terminal (component input terminal) 4 to which a luminance signal (Y) and two color-difference signals (R−Y), (B−Y), for example, are supplied, separately.

Further, the luminance signal (Y) and the two color-difference signals (R−Y), (B−Y) from the above-mentioned change-over switches 3R, 3B are each supplied to a converting circuit 6, in which they are converted into three primary color signals of red (R), green (G), blue (B), for example. The three primary color signals (R/G/B) thus converted by this converting circuit 6 are respectively supplied to gamma correction means (dynamic gamma circuits) 5R, 5G, 5B, each having a gamma correction curve controlled by an output control signal Vc from a control circuit 11 which will be described later on.

The dynamic gamma circuits 5R, 5G, 5B are controlled by the output control signal Vc from the control circuit 11, which will be described later on, in such a manner that an input and output gamma correction curve, for example, is presented as shown in FIG. 2, for example. Specifically, the dynamic gamma circuits 5R, 5G, 5B are controlled by the magnitude of the output control signal Vc in such a manner that the intermediate signal level of the gamma correction curve between input and output is increased from approximately a straight line as shown by an arrow in FIG. 2, for example. The three primary color signals (R/G/B) from the dynamic gamma circuits 5R, 5G, 5B are respectively supplied to A/D (analog-to-digital) converting circuits 7R, 7G, 7B. Further, resultant digital three primary color signals (R/G/B) are supplied from the A/D converting circuits 7R, 7G, 7B to a display device 8 such as a plasma display or a liquid-crystal display.

On the other hand, the luminance signal (Y) from the change-over switch 3Y is supplied to a comparing circuit 9 to be compared with an arbitrary reference level and thereby converted into a square-wave signal which goes to "0" when it is higher than the reference level and which goes to "1" when it is lower than the reference level. This square-wave signal is integrated by an integrating circuit 10 and thereby generated as the signal indicative of the average luminance level of the above-mentioned luminance signal (Y). Incidentally, this integrating circuit 10 is of a 5V-system circuit, for example. Therefore, the signal thus generated is supplied to the control circuit 11 which effects the voltage-conversion from 5V to 12V, for example, in order to establish an electrical interface between the integrating circuit 10 and the dynamic gamma circuits 5R, 5G, 5B. Then, the output control signal Vc thus voltage-converted by this control circuit 11 is supplied to the above-mentioned dynamic gamma circuits 5R, 5G, 5B.

In this manner, in this display device, the average luminance level of the luminance signal (Y) from the separating circuit 2 or the component input terminal 4 through the change-over switch 3Y is measured by the measuring means comprising the comparing circuit 9 to the control circuit 11. Further, the output control signal Vc corresponding to the average luminance level measured by this measuring means is supplied from the control circuit 11 to the dynamic gamma circuits 5R, 5G, 5B. Then, the gamma correction curves of the above-mentioned dynamic gamma circuits 5R, 5G, 5B are feedforward-controlled in such a fashion that the gamma correction between input and output becomes approximately a straight line when the average luminance level is large and that the intermediate signal level, for example, is increased when the average luminance level becomes small.

Accordingly, since this display device includes the measuring means for measuring the average luminance level of the video signal to be displayed and the gamma-correction means for three primary color signals controlled by the output control signal from this measuring means, the gamma correction curves of respective three primary color signals are controlled in response to the average luminance level of the video signal to be displayed, whereby the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark

scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily and a more accurate correction may be carried out.

Further, FIG. 13 is a block diagram showing a display device in which the three primary color signals of red (R), green (G), blue (B) are gamma-corrected according to a tenth embodiment of the present invention. In FIG. 13, the circuit arrangement provided ahead of the converting circuit 6 are omitted for convenience sake of sheets of drawings, and the arrangement of this portion is similar to that of FIG. 12.

Referring to FIG. 13, the luminance signal (Y) and the two color-difference signals (R–Y), (B–Y) from the above-mentioned change-over switches 3Y, 3R, 3B (not shown) are each supplied to a converting circuit 6. The three primary color signals of red (R), green (G), blue (B) thus converted by this converting circuit 6 are each supplied to change-over switches 14R, 14G, 14B, in which they are respectively switched from signals from an RGB input terminal 15 to which the three primary color signals (R/G/B), for example, are supplied independently.

Then, the three primary color signals (R/G/B) from the change-over switches 14R, 14G, 14B are respectively supplied to gamma correction means (dynamic gamma circuits) 5R, 5G, 5B, each having a gamma correction curve controlled by an output control signal Vc from a control circuit 11 which will be described later on. The dynamic gamma circuits 5R, 5G, 5B are each controlled by the output control signal Vc from the control circuit 11, which will be described later on, in such a manner that an input and output gamma correction curve, for example, is presented as shown in FIG. 2, for example. Specifically, the dynamic gamma circuits 5R, 5G, 5B are each controlled by the output control signal Vc in such a manner that the intermediate signal level of the gamma correction curve between input and output is increased from approximately a straight line as shown by an arrow in FIG. 2, for example.

Further, the corrected three primary color signals (R/G/B) from the dynamic gamma circuits 5R, 5G, 5B are respectively supplied to A/D (analog-to-digital) converting circuits 7R, 7G, 7B. Furthermore, resultant digital three primary color signals (R/G/B) are supplied from the A/D converting circuits 7R, 7G, 7B to a display device 8 such as a plasma display or a liquid-crystal display.

Also, the three primary color signals (R/G/B) from the above-mentioned change-over switches 14R, 14G, 14B are supplied to an analog luminance signal generating circuit 12A. This luminance signal generating circuit 12A generates a luminance signal (Y) by adding the three primary color signals (R/G/B) with a predetermined ratio, e.g. at a ratio of $Y=0.30R+0.59G+0.11B$ in the case of the NTSC system. The thus generated luminance signal (Y) is supplied to a comparing circuit 9, which compares a supplied luminance signal with an arbitrary reference level, and thereby converted into a square-wave signal which goes to "0" when it is higher than the reference level and which goes to "1" when it is lower than the reference level.

Further, an integrating circuit 10 integrates this square-wave signal to generate a signal indicative of the average luminance level of the above-mentioned luminance signal (Y). Incidentally, this integrating circuit 10 is of the 5V-system circuit, for example. Accordingly, the above-mentioned generated signal is supplied to the control circuit 11 which effects the voltage-conversion from 5V to 12V, for example, in order to establish the electrical interface with the above-mentioned dynamic gamma circuits 5R, 5G, 5B. Then, the output control signal Vc thus voltage-controlled by this control circuit 11 is supplied to the dynamic gamma circuits 5R, 5G, 5B.

As described above, according to this display device, the luminance signal (Y) is generated from the three primary color signals (R/G/B) from the change-over switches 14R, 14G, 14B. The average luminance level of the luminance signal (Y) is measured by the measuring means comprising the comparing circuit 9 to the control circuit 11. Further, the output control signal Vc, which corresponds to the average luminance level measured by this measuring means, from the control circuit 11 is supplied to the dynamic gamma circuits 5R, 5G, 5B. Then, the gamma correction curves of the above-mentioned dynamic gamma circuits 5R, 5G, 5B are feedforward-controlled in such a manner that the gamma correction between input and output becomes approximately a straight line when the average luminance level, for example, is large and that the intermediate signal level, for example, is increased when the average luminance level becomes small.

Accordingly, since this display device includes the measuring means for measuring the average luminance level of the video signal to be displayed and the gamma correction means for three primary color signals controlled by the output control signal from this measuring means, the gamma correction curves for the three primary color signals are controlled in response to the average luminance level of the video signal to be displayed, whereby the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily and may be corrected more accurately. At the same time, the display device according to this embodiment can cope with the RGB input terminal to which the three primary color signals are supplied independently.

Further, FIG. 14 is a block diagram showing a display device in which the three primary color signals of red (R), green (G), blue (B) are gamma-corrected according to an eleventh embodiment of the present invention. In FIG. 14, the circuit arrangement provided ahead of the converting circuit 6 is omitted for convenience sake of sheets of drawings, and the arrangement of this portion is similar to that of FIG. 12.

Referring to FIG. 14, the luminance signal (Y) and the two color-difference signals (R–Y), (B–Y) from the above-mentioned change-over switches 3Y, 3R, 3B (not shown) are each supplied to a converting circuit 6. The three primary color signals of red (R), green (G), blue (B) thus converted by this converting circuit 6 are each supplied to change-over switches 14R, 14G, 14B, in which they are respectively switched from signals from an RGB input terminal 15 to which the three primary color signals (R/G/B), for example, are supplied independently.

Then, the three primary color signals (R/G/B) from the change-over switches 14R, 14G, 14B are respectively supplied to gamma correction means (dynamic gamma circuits) 5R, 5G, 5B, each having a gamma correction curve controlled by an output control signal Vc from a control circuit 11 which will be described later on. The dynamic gamma

circuits 5R, 5G, 5B are controlled by the output control signal Vc from the control circuit 11, which will be described later on, in such a manner that an input and output gamma correction curve, for example, is presented as shown in FIG. 2, for example. Specifically, the dynamic gamma circuits 5R, 5G, 5B are controlled by the output control signal Vc in such a manner that the intermediate signal level of the gamma correction curve between input and output is increased from approximately a straight line as shown by an arrow in FIG. 2, for example.

Further, the corrected three primary color signals (R/G/B) from these dynamic gamma circuits 5R, 5G, 5B are respectively supplied to A/D (analog-to-digital) converting circuits 7R, 7G, 7B. Furthermore, resultant digital three primary color signals (R/G/B) are supplied from the A/D converting circuits 7R, 7G, 7B to a display device 8 such as a plasma display or a liquid-crystal display.

Also, the three primary color signals (R/G/B) from the above-mentioned dynamic gamma circuits 5R, 5G, 5B are supplied to an analog luminance signal generating circuit 12A. This luminance signal generating circuit 12A generates a luminance signal (Y) by adding the three primary color signals (R/G/B) with a predetermined ratio, e.g. at a ratio of Y=0.30R+0.59G+0.11B in the case of the NTSC system, for example. The thus generated luminance signal (Y) is supplied to a comparing circuit 9, which compares a supplied luminance signal with an arbitrary reference level, and thereby converted into a square-wave signal which goes to "0" when it is higher than the reference level and which goes to "1" when it is lower than the reference level.

Further, an integrating circuit 10 integrates this square-wave signal to generate a signal indicative of the average luminance level of the above-mentioned luminance signal (Y). Incidentally, this integrating circuit 10 is of the 5V-system circuit, for example. Accordingly, the above-mentioned generated signal is supplied to the control circuit 11 which effects the voltage-conversion from 5V to 12V, for example, in order to establish the electrical interface with the above-mentioned dynamic gamma circuits 5R, 5G, 5B. Then, the output control signal Vc thus voltage-controlled by this control circuit 11 is supplied to the dynamic gamma circuits 5R, 5G, 5B.

As described above, according to this display device, the luminance signal (Y) is generated from the corrected three primary color signals (R/G/B) from the dynamic gamma circuits 5R, 5G, 5B. The average luminance level of the luminance signal (Y) is measured by the measuring means comprising the comparing circuit 9 to the control circuit 11. Further, the output control signal Vc, which corresponds to the average luminance level measured by this measuring means, from the control circuit 11 is supplied to the dynamic gamma circuits 5R, 5G, 5B. Then, the gamma correction curves of the above-mentioned dynamic gamma circuits 5R, 5G, 5B are feedback-controlled in such a manner that the gamma correction between input and output becomes approximately a straight line when the average luminance level, for example, is large and that the intermediate signal level, for example, is increased when the average luminance level becomes small.

Accordingly, since this display device includes the measuring means for measuring the average luminance level of the video signal to be displayed and the gamma correction means for three primary color signals controlled by the output control signal from this measuring means, the gamma correction curves for the three primary color signals are controlled-in response to the average luminance level of the video signal to be displayed, whereby the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily and may be corrected more accurately. At the same time, the display device according to this embodiment can cope with the RGB input terminal to which the three primary color signals are supplied independently.

Further, FIG. 15 is a block diagram showing a display device in which the three primary color signals of red (R), green (G), blue (B) are gamma-corrected according to a twelfth embodiment of the present invention. Incidentally, also in FIG. 15, the circuit arrangement provided ahead of the converting circuit 6 is omitted for convenience sake of sheets of drawings, and the arrangement of this portion is similar to that of FIG. 12.

Referring to FIG. 15, the luminance signal (Y) and the two color-difference signals (R−Y), (B−Y) from the above-mentioned change-over switches 3Y, 3R, 3B (not shown) are each supplied to a converting circuit 6. Further, the three primary color signals of red (R), green (G), blue (B) thus converted by this converting circuit 6 are respectively supplied to change-over switches 14R, 14G, 14B, in which they are respectively switched from signals from an RGB input terminal 15 to which the three primary color signals (R/G/B), for example, are supplied independently.

Then, the three primary color signals (R/G/B) from the change-over switches 14R, 14G, 14B are respectively supplied to gamma correction means (dynamic gamma circuits) 5R, 5G, 5B, each having a gamma correction curve controlled by an output control signal Vc from a control circuit 11 which will be described later on. The dynamic gamma circuits 5R, 5G, 5B are controlled by the output control signal Vc from the control circuit 11, which will be described later on, in such a manner that an input and output gamma correction curve, for example, is presented as shown in FIG. 2, for example. Specifically, the dynamic gamma circuits 5R, 5G, 5B are controlled in response to the magnitude of the output control signal Vc in such a manner that the intermediate signal level of the gamma correction curve between input and output is increased from approximately a straight line as shown by an arrow in FIG. 2, for example.

Further, the corrected three primary color signals (R/G/B) from these dynamic gamma circuits 5R, 5G, 5B are respectively supplied to A/D (analog-to-digital) converting circuits 7R, 7G, 7B. Furthermore, resultant digital three primary color signals (R/G/B) are supplied from the A/D converting circuits 7R, 7G, 7B to a display device 8 such as a plasma display or a liquid-crystal display.

Also, the three primary color signals (R/G/B) thus digitally converted by the above-mentioned A/D converting circuits 7R, 7G, 7B are supplied to a digital luminance signal generating circuit 12D. The three primary color signals (R/G/B) outputted from the A/D converting circuits 7R, 7G, 7B are digital signals in which a sampling frequency, for example, is 30 MHz and the quantization bit number is 8 bits (quantization value ranges from 0 to 255). This luminance signal generating circuit 12D generates a luminance signal (Y: digital value) by adding the three primary color signals (R/G/B) with a predetermined ratio, e.g. at a ratio of Y=0.30R+0.59G+0.11B in the case of the NTSC system.

The thus generated luminance signal (Y: digital value) is supplied to a comparing circuit 9, which compares a sup-

plied luminance signal with an arbitrary reference level, e.g. quantization value 100, and thereby converted into a square-wave signal which goes to "0" when it is higher than the reference level and which goes to "1" when it is lower than the reference level. An integrating circuit **10** integrates this square-wave signal to generate a signal (analog value) indicative of the average luminance level of the above-mentioned luminance signal (Y). Incidentally, this integrating circuit **10** is of the 5V-system circuit, for example. Accordingly, the above-mentioned generated signal is supplied to the control circuit **11** which effects the voltage-conversion from 5V to 12V, for example, in order to establish the electrical interface between the above-mentioned dynamic gamma circuits **5R**, **5G**, **5B** and the integrating circuit **10**. Then, the output control signal Vc thus voltage-controlled by this control circuit **11** is supplied to the dynamic gamma circuits **5R**, **5G**, **5B**.

As described above, according to this display device, the luminance signal (Y: digital value) is generated from the three primary color signals (R/G/B) thus digitally converted by the A/D converting circuits **7R**, **7G**, **7B**, and the average luminance level (analog value) of this luminance signal (Y) is measured by the measuring means comprising the comparing circuit **9** to the control circuit **11**. Further, the output control signal Vc, which corresponds to the average luminance level measured by this measuring means, from the control circuit **11** is supplied to the dynamic gamma circuits **5R**, **5G**, **5B**. Then, the gamma correction curves of the above-mentioned dynamic gamma circuits **5R**, **5G**, **5B** are feedback-controlled in such a manner that the gamma correction between input and output becomes approximately a straight line when the average luminance level, for example, is large and that the intermediate signal level, for example, is increased when the average luminance level becomes small.

Accordingly, since this display device includes the measuring means for measuring the average luminance level of the video signal to be displayed and the gamma correction means for three primary color signals controlled by the output control signal from this measuring means, the gamma correction curves for the three primary color signals are controlled in response to the average luminance level of the video signal to be displayed, whereby the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily and may be corrected more accurately. At the same time, the display device according to this embodiment can cope with the RGB input terminal to which the three primary color signals are supplied independently.

Furthermore, in the above-mentioned apparatus, when more complex corrections matched with characteristics of the respective signals or the like are required, it is considered that the digitally-converted three primary color signals of red (R), green (G), blue (B), for example, may be corrected. In this case, when the three primary color signals of red (R), green (G), blue (B), for example, are gamma-corrected, these three primary color signals of red (R), green (G), blue (B) can be gamma-corrected similarly to the above-mentioned luminance signal (Y). Also, as a signal correction means, it is possible to use a read-only memory (ROM) and a so-called digital signal processor (DSP).

Specifically, FIG. **16** is a block diagram showing a display device in which the digitally-converted three primary color signals of red (R), green (G), blue (B), for example, are respectively gamma-corrected according to a thirteenth embodiment of the present invention.

Referring to FIG. **16**, the display device includes an input terminal **1** to which there is supplied a composite video signal (video signal), for example. The composite video signal from this input terminal **1** is supplied to a separating circuit **2** which separates the composite video signal, for example, to provide a luminance signal (Y) and two color-difference signals (R−Y), (B−Y). Further, the luminance signal (Y) and the two color-difference signals (R−Y) and (B−Y) separated by the separating circuit **2** are respectively supplied to change-over-switches **3Y**, **3R**, **3B**, in which they are switched from signals supplied from an input terminal (component input terminal) **4** to which a luminance signal (Y) and two color-difference signals (R−Y), (B−Y), for example, are supplied, separately.

Further, the luminance signal (Y) and the two color-difference signals (R−Y), (B−Y) from the above-mentioned change-over switches **3Y**, **3R**, **3B** are each supplied to a converting circuit **6**, in which they are converted into three primary color signals of red (R), green (G), blue (B), for example. The three primary color signals (R/G/B) thus converted by this converting circuit **6** are respectively supplied to A/D (analog-to-digital) converting circuits **7R**, **7G**, **7B**. Resultant digitally-converted three primary color signals (R/G/B) are respectively supplied to correction means (digital signal processors=DSP) **16R**, **16G**, **16B** having gamma correction curves or the like controlled by an output control digital signal from a digital control circuit **17** which will be described later on.

Here, the digital signal processors (DSP) **16R**, **16G**, **16B** are controlled by the output control digital signal from the digital control circuit **17**, which will be described later on, in such a manner that gamma correction characteristic curves between input and output are controlled as shown in FIG. **2**, for example. Specifically, the digital signal processors **16R**, **16G**, **16B** are controlled by the output control digital signal such a manner that the intermediate signal level of the gamma correction curve between input and output is increased from approximately a straight line as shown by an arrow in FIG. **2**, for example. The three primary color signals (R/G/B) from these digital signal processors (DSP) **16R**, **16G**, **16B** are supplied to a display device **8** such as a plasma display or a liquid-crystal display.

On the other hand, the luminance signal (Y) from the change-over switch **3Y** is supplied to a comparing circuit **9**, which compares a supplied signal with an arbitrary reference level, and thereby converted into a square-wave signal which goes to "0" when it is higher than the reference level and which goes to "1" when it is lower than the reference level. This square-wave signal is integrated by an integrating circuit **10** and thereby generated as a signal indicative of an average luminance level of the above-mentioned luminance signal (Y). Then, the signal indicative of the average luminance level from this integrating circuit **10** is supplied to the digital control circuit **17** which then generates the output control digital signal to control the above-mentioned digital signal processors (DSP) **16R**, **16G**, **16B**. Further, the output control digital signal generated by this digital control circuit **17** is supplied to the digital signal processors (DSP) **16R**, **16G**, **16B**.

As described above, according to this display device, the average luminance level of the luminance signal (Y) supplied from the separating circuit **2**, for example, or the component input terminal **4** through the change-over switch

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3Y is measured by the measuring means comprising the comparing circuit **9** and the integrating circuit **10**. Further, the output control digital signal corresponding to the average luminance level measured by this measuring means is generated by the digital control circuit **17** and then supplied to the digital signal processors (DSP) **16R**, **16G**, **16B**. Then, the gamma correction curves and the like of the above-mentioned digital signal processors (DSP) **16R**, **16G**, **16B** are feedforward-controlled in such a manner that the gamma correction between input and output becomes approximately a straight line when the average luminance level, for example, is large and that the intermediate signal level is increased when the average luminance level becomes small.

Accordingly, since this display device includes the measuring means for measuring the average luminance level of the video signal to be displayed and the gamma correction means for each of three primary color signals controlled by the output control signal from this measuring means, the gamma correction curve for each of the three primary color signals is controlled in response to the average luminance level of the video signal to be displayed, whereby the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily. Also, since the digital processing is used, a more complex correction matched with the characteristics of the respective signals may be carried out. At the same time, the display device according to this embodiment can cope with the RGB input terminal to which the three primary color signals are supplied independently.

Further, FIG. **17** is a block diagram showing a display device in which the digitally-converted three primary color signals of red (R), green (G), blue (B), for example, are respectively gamma-corrected according to a fourteenth embodiment of the present invention. Incidentally, in FIG. **17**, the circuit arrangement provided ahead of the converting circuit **6** is omitted for convenience sake of sheets of drawings, and the arrangement of this portion is similar to that of FIG. **16**.

Referring to FIG. **17**, the luminance signal (Y) and the two color-difference signals (R−Y), (B−Y) from the above-mentioned change-over switches **3Y**, **3R**, **3*b*** (not shown) are each supplied to a converting circuit **6**. Further, the three primary color signal of red (R), green (G), blue (B), for example, thus converted by this converting circuit **6** are each supplied to change-over switches **14R**, **14G**, **14B**, in which they are switched from signals from an RGB input terminal **15** to which three primary color signals (R/G/B), for example, are supplied independently.

The three primary color signals (R/G/B) from the change-over switches **14R**, **14G**, **14B** are respectively supplied to A/D converting circuits **7R**, **7G**, **7B**. Further, the thus digitally-converted three primary color signals (R/G/B) are respectively supplied to correction means (digital signal processors=DSP) **16R**, **16G**, **16B** having gamma correction curves or the like controlled by an output control digital signal from a digital control circuit **17** which will be described later on.

Here, the digital signal processors (DSP) **16R**, **16G**, **16B** are controlled by the output control digital signal from the digital control circuit **17**, which will be described later on, in such a manner that gamma correction characteristic curves between input and output thereof are controlled as shown in FIG. **2**, for example. Specifically, the digital signal processors **16R**, **16G**, **16B** are controlled by the magnitude of the output control digital signal in such a manner that the intermediate signal level of the gamma correction curve between input and output is increased from approximately a straight line as shown by an arrow in FIG. **2**, for example. The three primary color signals (R/G/B) from these digital signal processors (DSP) **16R**, **16G**, **16B** are supplied to a display device **8** such as a plasma display or a liquid-crystal display.

Also, the three primary color signals (R/G/B) from the above-mentioned change-over switches **14R**, **14G**, **14B** are supplied to an analog luminance signal generating circuit **12A**. This luminance signal generating circuit **12A** generates a luminance signal (Y) by adding the three primary color signals (R/G/B) with a predetermined ratio, e.g. with a ratio of $Y=0.30R+0.59G+0.11B$ in the case of the NTSC system. The thus generated luminance signal (Y) is supplied to a comparing circuit **9**, which compares a supplied luminance signal with an arbitrary reference level, and thereby converted into a square-wave signal which goes to "0" when it is higher than the reference level and which goes to "1" when it is lower than the reference level.

Further, an integrating circuit **10** integrates this square-wave signal to generate a signal indicative of the average luminance level of the above-mentioned luminance signal (Y). Then, the signal indicative of the average luminance level from this integrating circuit **10** is supplied to the digital control circuit **17** which then generates the output control digital signal to control the above-mentioned digital signal processors (DSP) **16R**, **16G**, **16B**. Further, the output control digital signal generated at this digital control circuit **17** is supplied to the digital signal processors (DSP) **16R**, **16G**, **16B**.

As described above, according to this display device, the luminance signal (Y) is generated from the three primary color signals (R/G/B) from the change-over switches **14R**, **14G**, **14B**. The average luminance level of the luminance signal (Y) is measured by the measuring means comprising the comparing circuit **9** and the integrating circuit **10**. Further, the output control digital signal corresponding to the average luminance level measured by this measuring means is generated by the digital control circuit **17** and then supplied to the digital signal processors (DSP) **16R**, **16G**, **16B**. Then, the gamma correction curves and the like of the above-mentioned digital signal processors (DSP) **16R**, **16G**, **16B** are feedforward-controlled in such a manner that the gamma correction between input and output becomes approximately a straight line when the average luminance level, for example, is large and that the intermediate signal level is increased when the average luminance level becomes small.

Accordingly, since this display device includes the measuring means for measuring the average luminance level of the video signal to be displayed and the gamma correction means for each of three primary color signals controlled by the output control signal from this measuring means, the gamma correction curve for each of the three primary color signals is controlled in response to the average luminance level of the video signal to be displayed, whereby the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation

of bright portion may be expressed satisfactorily. Since the digital processing is used, a more complex correction matched with the characteristics of the respective signals or the like may be carried out. At the same time, the display device according to this embodiment can cope with the RGB input terminal to which the three primary color signals are supplied independently.

Also, FIG. 18 is a block diagram showing a display device in which the digitally-converted three primary color signals of red (R), green (G), blue (B), for example, are respectively gamma-corrected according to a fifteenth embodiment of the present invention. Incidentally, in FIG. 18, the circuit arrangement provided ahead of the converting circuit 6 is omitted for convenience sake of sheets of drawings, and the arrangement of this portion is similar to that of FIG. 16.

Referring to FIG. 18, the luminance signal (Y) and the two color-difference signals (R−Y), (B−Y) from the above-mentioned change-over switches 3Y, 3R, 3B (not shown) are each supplied to a converting circuit 6. Further, the three primary color signal of red (R), green (G), blue (B), for example, thus converted by this converting circuit 6 are respectively supplied to change-over switches 14R, 14G, 14B, in which they are switched from signals from an RGB input terminal 15 to which three primary color signals (R/G/B), for example, are supplied independently.

The three primary color signals (R/G/B) from the change-over switches 14R, 14G, 14B are respectively supplied to A/D converting circuits 7R, 7G, 7B. Further, the thus digitally-converted three primary color signals (R/G/B) in the A/D converting circuits 7R, 7G, 7B are respectively supplied to change-over switches 18R, 18G, 18B, in which they are switched from signals from RGB digital input terminals 19 to which the digitally-converted three primary color signals (R/G/B) are supplied independently. Also, the digital three primary color signals (R/G/B) from the change-over switches 18R, 18G, 18B are respectively supplied to correction means (digital signal processors=DSP) 16R, 16G, 16B having gamma correction curves or the like controlled by an output control digital signal from a digital control circuit 17 which will be described later on.

Here, the digital signal processors (DSP) 16R, 16G, 16B are controlled by the output control digital signal from the digital control circuit 17, which will be described later on, in such a manner that gamma correction characteristic curves between input and output thereof are controlled as shown in FIG. 2, for example. Specifically, the digital signal processors 16R, 16G, 16B are controlled in such a manner that the intermediate signal level of the gamma correction curve between input and output is increased from approximately a straight line in response to the magnitude of the output control digital signal as shown by an arrow in FIG. 2, for example. The three primary color signals (R/G/B) from these digital signal processors (DSP) 16R, 16G, 16B are supplied to a display device 8 such as a plasma display or a liquid-crystal display.

Also, the digital three primary color signals (R/G/B) from the above-mentioned change-over switches 18R, 18G, 18B are supplied to a digital luminance signal generating circuit 12D. Here, the digital three primary color signals (R/G/B) derived from the change-over switches 18R, 18G, 18B are digital signals in which a sampling frequency, for example, is 30 MHz and a quantization bit number is 8 bits (quantization value ranges from 0 to 255). Accordingly, the above-mentioned luminance signal generating circuit 12D generates a luminance signal (Y: digital value) by adding the three primary color signals (R/G/B) of the digital values with a predetermined ratio, e.g. with a ratio of $Y=0.30R+0.59G+0.11B$ in the case of the NTSC system.

Further, the thus generated luminance signal (Y: digital value) is supplied to a comparing circuit 9, which compares a supplied luminance signal with an arbitrary reference level, e.g. quantization value 100, and thereby converted into a square-wave signal which goes to "0" when it is higher than the reference level and which goes to "1" when it is lower than the reference level. Then, an integrating circuit 10 integrates this square-wave signal to generate a signal indicative of the average luminance level of the above-mentioned luminance signal (Y). Then, the signal indicative of the average luminance level from this integrating circuit 10 is supplied to the digital control circuit 17 which then generates the output control digital-signal to control the above-mentioned digital signal processors (DSP) 16R, 16G, 16B. Further, the output control digital signal generated at this digital control circuit 17 is supplied to the digital signal processors (DSP) 16R, 16G, 16B.

As described above, according to this display device, the luminance signal (Y: digital value) is generated from the digital three primary color signals (R/G/B) supplied from the A/D converting circuits 7R, 7G, 7B or the RGB input terminals 19 through the change-over switches 18R, 18G, 18B. The average luminance level of this luminance signal (Y) is measured by the measuring means comprising the comparing circuit 9 and the integrating circuit 10. Further, the output control digital signal corresponding to the average luminance level measured by this measuring means is generated by the digital control circuit 17 and then supplied to the digital signal processors (DSP) 16R, 16G, 16B. Then, the gamma correction curves and the like of the above-mentioned digital signal processors (DSP) 16R, 16G, 16B are feedforward-controlled in such a manner that the gamma correction between input and output becomes approximately a straight line when the average luminance level, for example, is large and that the intermediate signal level is increased, for example, when the average luminance level becomes small.

Accordingly, since this display device includes the measuring means for measuring the average luminance level of the video signal to be displayed and the gamma correction means for each of three primary color signals controlled by the output control signal from this measuring means, the gamma correction curves for the three primary color signals are respectively controlled in response to the average luminance level of the video signal to be displayed, whereby the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily. Since the digital processing is used, a more complex correction matched with the characteristics of the respective signals or the like may be carried out. At the same time, the display device according to this embodiment can cope with the RGB input terminals to which the three primary color signals are supplied independently.

Further, FIG. 19 is a block diagram showing a display device in which the digitally-converted three primary color signals of red (R), green (G), blue (B), for example, are respectively gamma-corrected according to a sixteenth embodiment of the present invention. Incidentally, also in FIG. 19, the circuit arrangement provided ahead of the converting circuit 6 is omitted for convenience sake of

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sheets of drawings, and the arrangement of this portion is similar to that of FIG. 16.

As shown in FIG. 19, the luminance signal (Y) and the two color-difference signals (R−Y), (B−Y) from the above-mentioned change-over switches 3Y, 3R, 3B (not shown) are each supplied to a converting circuit 6. Further, the three primary color signal of red (R), green (G), blue (B), for example, thus converted by this converting circuit 6 are respectively supplied to change-over switches 14R, 14G, 14B, in which they are respectively switched from signals from an RGB input terminal 15 to which three primary color signals (R/G/B), for example, are respectively supplied independently.

The three primary color signals (R/G/B) from the change-over switches 14R, 14G, 14B are respectively supplied to A/D converting circuits 7R, 7G, 7B. Further, the thus digitally-converted three primary color signals (R/G/B) by the A/D converting circuits 7R, 7G, 7B are respectively supplied to change-over switches 18R, 18G, 18B, in which they are respectively switched from the signals from the RGB digital input terminals 19 to which the digitally-converted three primary color signals (R/G/B) are respectively supplied independently. Also, the digital three primary color signals (R/G/B) from the change-over switches 18R, 18G, 18B are respectively supplied to correction means (digital signal processors=DSP) 16R, 16G, 16B having gamma correction curves or the like controlled by an output control digital signal from a digital control circuit 17 which will be described later on.

Here, the digital signal processors (DSP) 16R, 16G, 16B are controlled by the output control digital signal from the digital control circuit 17, which will be described later on, in such a manner that gamma correction characteristic curves between input and output thereof are controlled as shown in FIG. 2, for example. Specifically, the digital signal processors 16R, 16G, 16B controlled in such a manner that the intermediate signal level of the gamma correction curve between input and output is increased from approximately a straight line in response to the magnitude of the output control digital signal as shown by an arrow in FIG. 2, for example. Then, the three primary color signals (R/G/B) from these digital signal processors (DSP) 16R, 16G, 16B are supplied to a display device 8 such as a plasma display or a liquid-crystal display.

Also, the corrected three primary color signals (R/G/B) from the above-mentioned digital signal processors (DSP) 16R, 16G, 16B are supplied to a digital luminance signal generating circuit 12D. Here, the three primary color signals (R/G/B) derived from the digital signal processors (DSP) 16R, 16G, 16B are digital signals in which a sampling frequency, for example, is 30 MHz and a quantization bit number is 8 bits (quantization value ranges from 0 to 255). Accordingly, the above-mentioned luminance signal generating circuit 12D generates a luminance signal (Y: digital value) by adding the three primary color signals (R/G/B) of the digital values with a predetermined ratio, e.g. with a ratio of Y=0.30R+0.59G+0.11B in the case of the NTSC system.

Further, the thus generated luminance signal (Y: digital value) is supplied to a comparing circuit 9, which compares a supplied luminance signal with an arbitrary reference level, e.g. quantization value 100, and thereby converted into a square-wave signal which goes to "0" when it is higher than the reference level and which goes to "1" when it is lower than the reference level. Then, an integrating circuit 10 integrates this square-wave signal to generate a signal (analog value) indicative of the average luminance level of the above-mentioned luminance signal (Y). Then, the signal indicative of the average luminance level from this integrating circuit 10 is supplied to the digital control circuit 17 which then generates the output control digital signal to control the above-mentioned digital signal processors (DSP) 16R, 16G, 16B. Further, the output control digital signal generated at this digital control circuit 17 is supplied to the digital signal processors (DSP) 16R, 16G, 16B.

As described above, according to this display device, the luminance signal (Y: digital value) is generated from the digital three primary color signals (R/G/B) supplied from the A/D converting circuits 7R, 7G, 7B or the RGB input terminals 19 through the change-over switches 18R, 18G, 18B. The average luminance level of this luminance signal (Y) is measured by the measuring means comprising the comparing circuit 9 and the integrating circuit 10. Further, the output control digital signal corresponding to the average luminance level measured by this measuring means is generated by the digital control circuit 17 and then supplied to the digital signal processors (DSP) 16R, 16G, 16B. Then, the gamma correction curves and the like of the above-mentioned digital signal processors (DSP) 16R, 16G, 16B are feedback-controlled in such a manner that the gamma correction between input and output becomes approximately a straight line when the average luminance level, for example, is large and that the intermediate signal level is increased, for example, when the average luminance level becomes small.

Accordingly, since this display device includes the measuring means for measuring the average luminance level of the video signal to be displayed and the gamma correction means for respective three primary color signals controlled by the output control signal from this measuring means, the gamma correction curves for the three primary color signals are respectively controlled in response to the average luminance level of the video signal to be displayed, whereby the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily. Since the digital processing is used, a more complex correction matched with the characteristics of the respective signals or the like may be carried out. At the same time, the display device according to this embodiment can cope with the RGB input terminals to which the three primary color signals are supplied independently.

Incidentally, in the above-mentioned display devices, when the external circuit arrangement includes a sub-contrast adjustment and a luminance level adjustment, such extra gains thereof may be appropriated for the gain control in the above-mentioned dynamic gamma circuit. Thus, it is possible to realize a display device of a simpler arrangement inexpensively.

Furthermore, the present invention is not limited the display device using the display means such as the plasma display or the liquid-crystal display, and may be applied to display devices using a cathode-ray tube and other display means.

Therefore, according to the first invention, since the display device includes measuring means for measuring an average luminance level of the luminance signal supplied from the separating circuit or video signal input terminal or

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the three primary color signals supplied from the converting circuit or the primary color signal input terminals or the digitally-converted three primary color signals supplied from the A/D converting means or digital input terminals and gamma correction means having a gamma correction curve controlled by an output control signal from the measuring means, the gamma correction curve is controlled in response to the average luminance level of the video signal to be displayed. Therefore, the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily.

The problems with which the related-art display device encounters are that an image becomes difficult to see in the scene in which the object luminance level is low and that when the whole contrast is increased, in the scene in which only one portion is bright in the whole of the dark object, for example, this bright portion becomes the so-called white compression so that the gradation of this portion cannot be expressed. According to the present invention, it is possible to solve these problems with ease.

Also, according to the second invention, the measuring means comprises a comparing means for being supplied with an analog luminance signal from the separating circuit or the video signal input terminals as an input and for comparing the analog luminance signal with a predetermined level, an integrating circuit for integrating an output from the comparing circuit and a control circuit for generating the output control signal based on an integrated value from the integrating circuit. Thus, the analog luminance signal may be measured satisfactorily, and the satisfactory correction may be carried out.

Further, according to the third invention, the measuring means comprises an analog luminance signal generating circuit comprises for being supplied with analog three primary color signals supplied from the converting circuit or the primary color signal input terminals and for generating an analog luminance signal by adding the three primary color signals with a predetermined ratio, a comparing circuit for comparing the generated analog luminance signal with a predetermined level, an integrating circuit for integrating an output from the comparing circuit and a control circuit for generating the output control signal based on an integrated value from the integrating circuit. Thus, the analog three primary color signals may be measured satisfactorily, and the satisfactory correction may be carried out.

Also, according to the fourth invention, the measuring means comprises a digital luminance signal generating circuit for being supplied with the digitally-converted three primary color signals from the A/D converting means or the digital input terminals and for generating a digital luminance signal by adding the digitally-converted three primary color signals with a predetermined ratio, a comparing circuit for comparing the generated digital luminance signal with a predetermined level, an integrating circuit for integrating an output from the integrating circuit and a control circuit for generating the output control signal based on an integrated value from the integrating circuit. Thus, the digitally-converted three primary color signals may be measured satisfactorily, and the satisfactory correction may be carried out.

According to the fifth invention, since the gamma correction curve of the gamma correction means has a control characteristic such that the gamma correction curve becomes approximately a straight line when the level of the output control signal from the measuring means is large and that an intermediate signal level is increased as the level of the output control signal from the measuring means is lowered, the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily.

Also, according to the sixth invention, since the gamma correction means is provided with respect to the analog luminance signal from the separating circuit or the video signal input terminal, the output control signal from the measuring means is generated based on the analog luminance signal from the separating circuit or the video signal input terminal and the gamma correction means is feedforward-controlled by the output control signal from the measuring means, the gamma correction curve is controlled in response to the average luminance level of the video signal to be displayed. Thus, the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily.

Further, according to the seventh invention, since the gamma correction means is provided with respect to the analog luminance signal from the separating circuit or the video signal input terminal, the output control signal from the measuring means is generated based on the analog luminance signal from the gamma correction means, and the gamma correction means is feedback-controlled by the output control signal from the measuring means, the gamma correction curve is controlled in response to the average luminance level of the video signal to be displayed. Thus, the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily.

Further, according to the eighth invention, since the gamma correction means is provided with respect to the analog luminance signal from the separating circuit or the video signal input terminal, the output control signal from the measuring means is generated based on the analog these primary color signals outputted from the converting circuit and the gamma correction means is feedback-controlled by the output control signal from the measuring means, the gamma correction curve is controlled in response to the average luminance level of the video signal to be displayed. Thus, the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily.

Further, according to the ninth invention, since the gamma correction means is provided with respect to the analog

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luminance signal from the separating circuit or the video signal input terminal, the output control signal from the measuring means is generated based on the digitally-converted three primary color signals outputted from the A/D converting means and the gamma correction means is feedback-controlled by the output control signal from the measuring means, the gamma correction curve is controlled in response to the average luminance level of the video signal to be displayed. Thus, the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily.

Also, according to the tenth invention, since the gamma correction means is provided with respect to the analog luminance signal supplied from the separating circuit or the video signal input terminal, color gain control means is provided in order to control levels of two color-difference signals comprising the video signal in response to the measured average luminance level, the output control signal from the measuring means is generated based on the analog luminance signal supplied from the separating circuit or the video signal input terminal and the gamma correction means and the color gain control means are feedforward-controlled by the output control signal from the measuring means, the gamma correction curve and the color gain are controlled in response to the average luminance level of the video signal to be displayed. Thus, the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily. Moreover, the color gain may be controlled satisfactorily in response to the change of this luminance level.

Further, according to the eleventh invention, since the gamma correction means is provided with respect to the analog luminance signal supplied from the separating circuit or the video signal input terminal, color gain control means is provided in order to control levels of two color-difference signals comprising the video signal in response to the measured average luminance level, the output control signal from the measuring means is generated based on the analog luminance signal supplied from the gamma correction means and the gamma correction means and the color gain control means are feedback-controlled by the output control signal from the measuring means, the gamma correction curve and the color gain are controlled in response to the average luminance level of the video signal to be displayed. Thus, the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily. Moreover, the color gain may be controlled satisfactorily in response to the change of this luminance level.

Further, according to the twelfth invention, since the gamma correction means is provided with respect to the analog luminance signal supplied from the separating circuit or the video signal input terminal, color gain control means is provided in order to control levels of two color-difference signals comprising the video signal in response to the measured average luminance level, the output control signal from the measuring means is generated based on the analog three primary color signals outputted from the converting means, and the gamma correction means and the color gain control means are feedback-controlled by the output control signal from the measuring means, the gamma correction curve and the color gain are controlled in response to the average luminance level of the video signal to be displayed. Thus, the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily. Moreover, the color gain may be controlled satisfactorily in response to the change of this luminance level.

Further, according to the thirteenth invention, since the gamma correction means is provided with respect to the analog luminance signal supplied from the separating circuit or the video signal input terminal, color gain control means is provided in order to control levels of two color-difference signals comprising the video signal in response to the measured average luminance level, the output control signal from the measuring means is generated based on the digitally-converted three primary color signals outputted from the A/D converting means and the gamma correction means and the color gain control means are feedback-controlled by the output control signal from the measuring means, the gamma correction curve and the color gain are controlled in response to the average luminance level of the video signal to be displayed. Thus, the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily. Moreover, the color gain may be controlled satisfactorily in response to the change of this luminance level.

According to the fourteenth invention, since the gamma correction means are respectively provided with respect to the three primary color signals outputted from the converting circuit, the output control signal from the measuring means is generated based on the analog luminance signal supplied from the separating circuit or the video signal input terminal and the gamma correction means are respectively feedforward-controlled by the output control signal from the measuring means, the gamma correction curves of the three primary color signals are respectively controlled in response to the average luminance level of the video signal to be displayed. Thus, the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily, and a more accurate correction may be carried out.

Also, according to the fifteenth invention, since the gamma correction means are respectively provided with

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respect to the three primary color signals outputted from the converting circuit or the primary color signal input terminals, the output control signal from the measuring means is generated based on the analog three primary color signals supplied from the converting circuit or the primary color signal input terminals and the gamma correction means are respectively feedforward-controlled by the output control signal from the measuring means, the gamma correction curves of the three primary color signals are respectively controlled in response to the average luminance level of the video signal to be displayed. Thus, the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily, and a more accurate correction may be carried out. Also, the display device according to the fifteenth invention may cope with the RGB input terminals to which the three primary color signals are supplied independently.

Further, according to the sixteenth invention, since the gamma correction means are respectively provided with respect to the three primary color signals supplied from the converting circuit or the primary color signal input terminals, the output control signal from the measuring means is generated based on the analog three primary color signals outputted from the gamma correction means and the gamma correction means are respectively feedback-controlled by the output control signal from the measuring means, the gamma correction curves of the three primary color signals are respectively controlled in response to the average luminance level of the video signal to be displayed. Thus, the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily, and a more accurate correction may be carried out. Also, the display device according to the sixteenth invention may cope with the RGB input terminals to which the three primary color signals are supplied independently.

Further, according to the seventeenth invention, since the gamma correction means are respectively provided with respect to the three primary color signals supplied from the converting circuit or the primary color signal input terminals, the output control signal from the measuring means is generated based on the digitally-converted three primary color signals outputted from the A/D converting means and the gamma correction means are respectively feedback-controlled by the output control signal from said measuring means, the gamma correction curves of the three primary color signals are respectively controlled in response to the average luminance level of the video signal to be displayed. Thus, the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily, and a more accurate correction may be carried out. Also, the display device according to the seventeenth invention may cope with the RGB input terminals to which the three primary color signals are supplied independently.

Further, according to the eighteenth invention, since the gamma correction means are respectively provided with respect to the digitally-converted three primary color signals outputted from the A/D converting means, the output control signal from the measuring means is generated based on the analog luminance signal supplied from the separating circuit or the video signal input terminals and the gamma correction means are respectively feedforward-controlled by the output control signal from the measuring means, the gamma correction curves of the three primary color signals are respectively controlled in response to the average luminance level of the video signal to be displayed, for example. Thus, the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily. Also, since the digital processing is used, a more complex correction matched with the characteristics of the respective signals or the like may be carried out. Moreover, the display device according to the eighteenth invention may cope with the RGB input terminals to which the three primary color signals are supplied independently.

Further, according to the nineteenth invention, since the gamma correction means are respectively provided with respect to the digitally-converted three primary color signals outputted from the A/D converting means, the output control signal from the measuring means is generated based on the analog three primary color signals supplied from the converting circuit or the primary color input terminals and the gamma correction means are respectively feedforward-controlled by the output control signal from said measuring means, the gamma correction curves of the three primary color signals are respectively controlled in response to the average luminance level of the video signal to be displayed. Thus, the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily. Also, since the digital processing is used, a more complex correction matched with the characteristics of the respective signals or the like may be carried out. Moreover, the display device according to the nineteenth invention may cope with the RGB input terminals to which the three primary color signals are supplied independently.

Further, in accordance with the twentieth invention, since the gamma correction means are respectively provided with respect to the digitally-converted three primary color signals supplied from the A/D converting means or the digital input terminals, the output control signal from the measuring means is generated based on the digitally-converted three primary color signals supplied from the A/D converting means or the digital input terminals and the gamma correction means are respectively feedforward-controlled by the output control signal from the measuring means, the gamma correction curves of the three primary color signals are respectively controlled in response to the average luminance level of the video signal to be displayed. Thus, the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal

is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily. Also, since the digital processing is used, a more complex correction matched with the characteristics of the respective signals or the like may be carried out. Moreover, the display device according to the twentieth invention may cope with the RGB input terminals and the digital RGB input terminals to which the three primary color signals are supplied independently.

Furthermore, in accordance with the twenty-first invention, since the gamma correction means are respectively provided with respect to the three primary color signals supplied from the A/D converting means or the digital input terminals, the output control signal from the measuring means is generated based on the digital three primary color signals outputted from the gamma correction means and the gamma correction means are respectively feedback-controlled by the output control signal from the measuring means, the gamma correction curves of the three primary color signals are respectively controlled in response to the average luminance level of the video signal to be displayed. Thus, the intermediate luminance level increases in the scene in which a luminance level of an object is low to thereby make an image of a dark scene become easy to see. At the same time, in that case, since the maximum output of the video signal is held at the constant level, even in the scene in which one portion is bright in the whole of the dark object, a gradation of bright portion may be expressed satisfactorily. Also, since the digital processing is used, a more complex correction matched with the characteristics of the respective signals or the like may be carried out. Moreover, the display device according to the twenty-first invention may cope with the RGB input terminals and the digital RGB input terminals to which the three primary color signals are supplied independently.

Having described preferred embodiments of the invention with reference to the accompanying drawings, it is to be understood that the invention is not limited to those precise embodiments and that various changes and modifications could be effected therein by one skilled in the art without departing from the spirit or scope of the invention as defined in the appended claims.

What is claimed is:

1. A display device comprising:

a measuring means for measuring an average luminance level of a video signal;

a gamma correction means for correcting an output signal level of the video signal corresponding to an input signal level of the video signal responsive to a gamma correction curve, the gamma correction means changing the gamma correction curve responsive to the average luminance level by changing the gamma correction curve to being approximately linear when the average luminance level is a maximum value, and the gamma correction means changing the gamma correction curve to being curvilinear, with an intermediate portion of the gamma correction curve having a greater value than when the gamma correction curve is approximately linear, when the average luminance level is less than the maximum value; and

a display means for displaying an image according to said output signal level of the video signal corrected by the gamma correction means.

2. A display device as claimed in claim 1, wherein said measuring means comprises a comparing circuit for comparing a luminance level of said video signal with a predetermined level and an integrating circuit for integrating an output from said comparing circuit, and a control circuit for generating a control signal for controlling the gamma correction means based on an integrated value from said integrated circuit.

3. A display device as claimed in claim 1, wherein said measuring means measures said average luminance level of said video signal which is supplied to said gamma correction means, and said gamma correction means is feedforward controlled by said a control signal from said measuring means.

4. A display device as claimed in claim 1, wherein said measuring means measures said average luminance level of said video signal which is supplied from said gamma correction means, and said gamma correction means is feedback controlled by a control signal from said measuring means.

5. A display device as claimed in claim 1, further comprising:

a separating circuit for separating said video signal to provide a luminance signal and color difference signals; and

a color gain control means for controlling gains for said color difference signals according to said average luminance level based on said luminance signal measured by said measuring means.

6. A display device as claimed in claim 5, wherein said gains of said color difference signals are controlled to increase when said average luminance level is increased.

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